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Nugent

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(54) **LOW FLOW POWER PLANT**

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(22) Filed: **Feb. 10, 2013**

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Related U.S. Application Data

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(51) **Int. Cl.**

F03B 7/00	(2006.01)
F03G 3/04	(2006.01)
F03B 17/06	(2006.01)
F03B 17/04	(2006.01)

(52) **U.S. Cl.**

CPC . ***F03B 7/00*** (2013.01); ***F03B 17/04*** (2013.01); *Y02E 10/20* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

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Primary Examiner — Christopher Jetton

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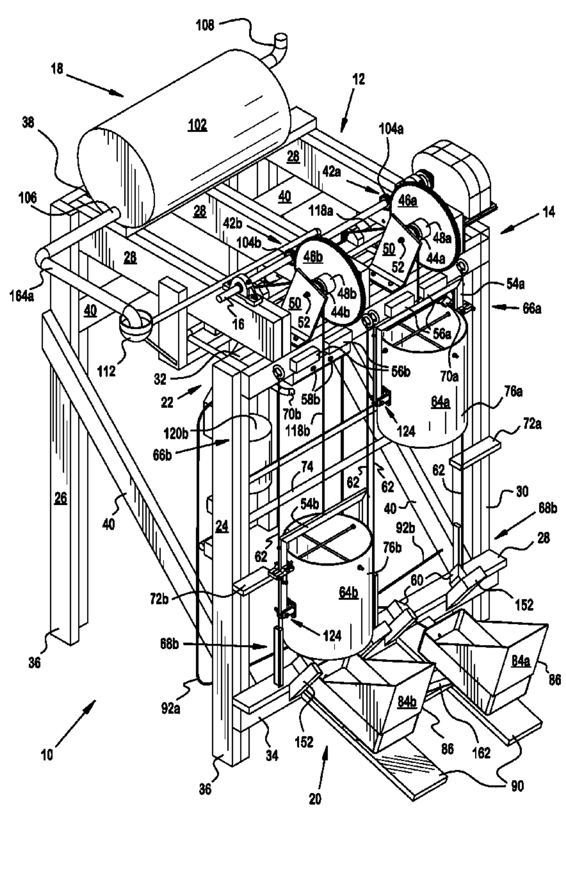
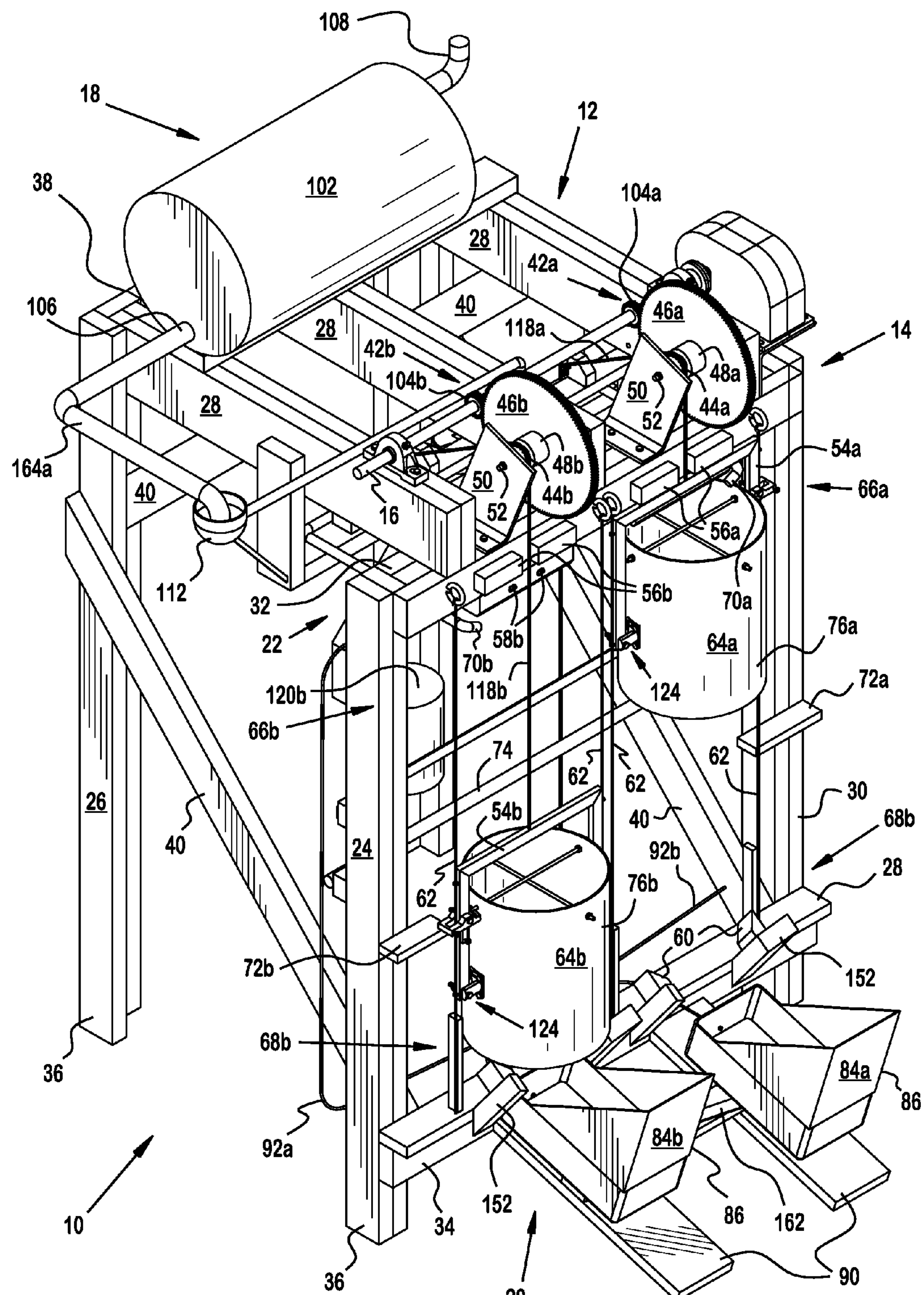
(57) **ABSTRACT**

A power plant and method for harnessing power from a source of working fluid. The power plant may include a power shaft that includes a first power gear, a first reciprocating engine situated proximate to the power shaft and connected to the first power gear for delivering a power stroke. The first reciprocating engine may include a first bucket assembly which comprises a first bucket mounting frame, a first bucket, and a first connecting mechanism that connects the first bucket to the first bucket mounting frame to form a first hinge that pivots about a first pivot axis such that the first bucket creates a turning moment about the first pivot axis, and a first locking mechanism for selectively locking the first bucket in the first bucket mounting frame.

18 Claims, 18 Drawing Sheets

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164a
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44b
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52
56a
112
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56b
70a
22
58b
76a
70b
64a
118b
124
72a
120b
66b
74
62
62
62
62
26
54b
30
24
40
68b
40
92b
28
62
76b
60
152
72b
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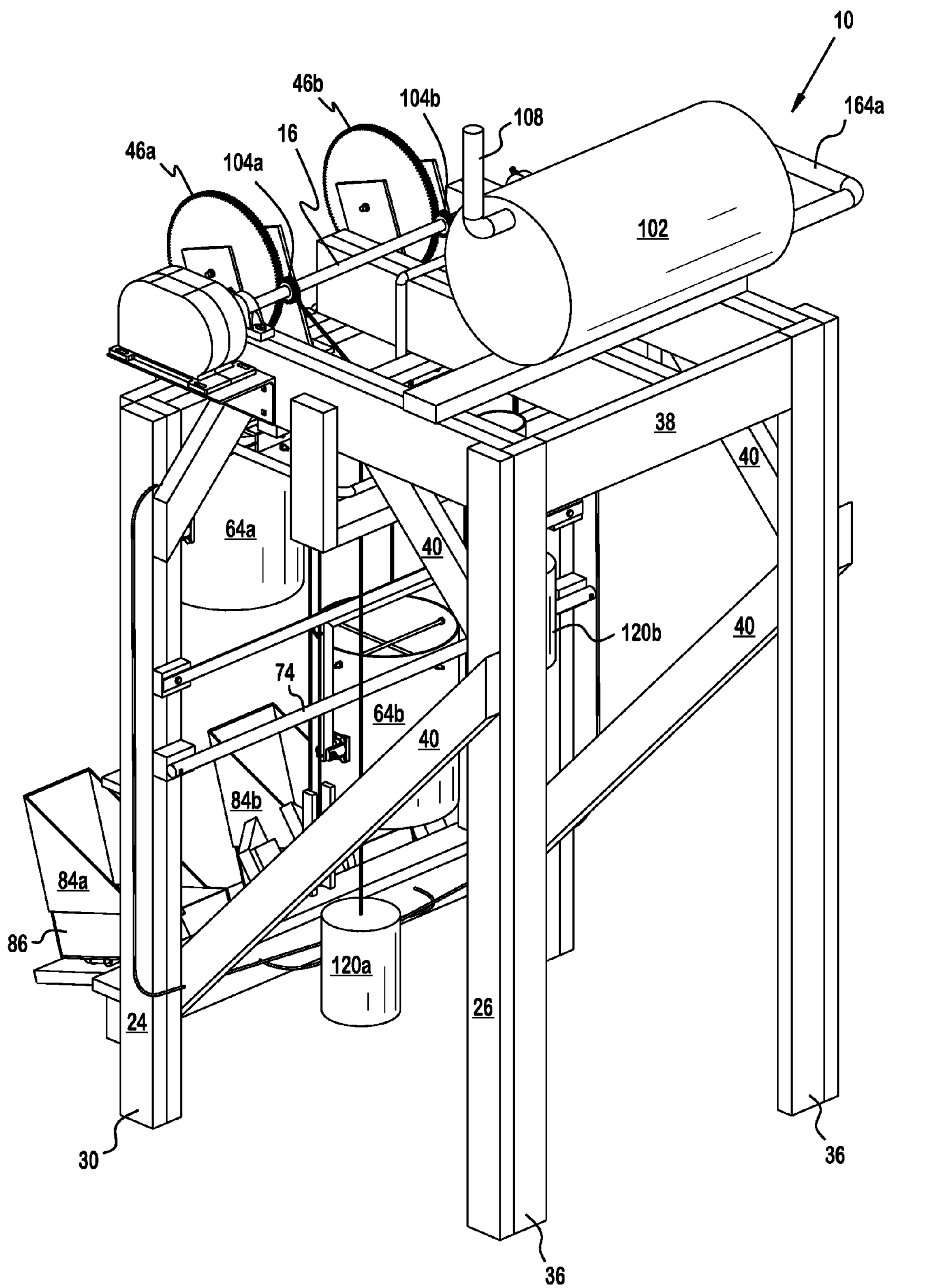
86
162
10
34
36
36
20
90

FIG. 1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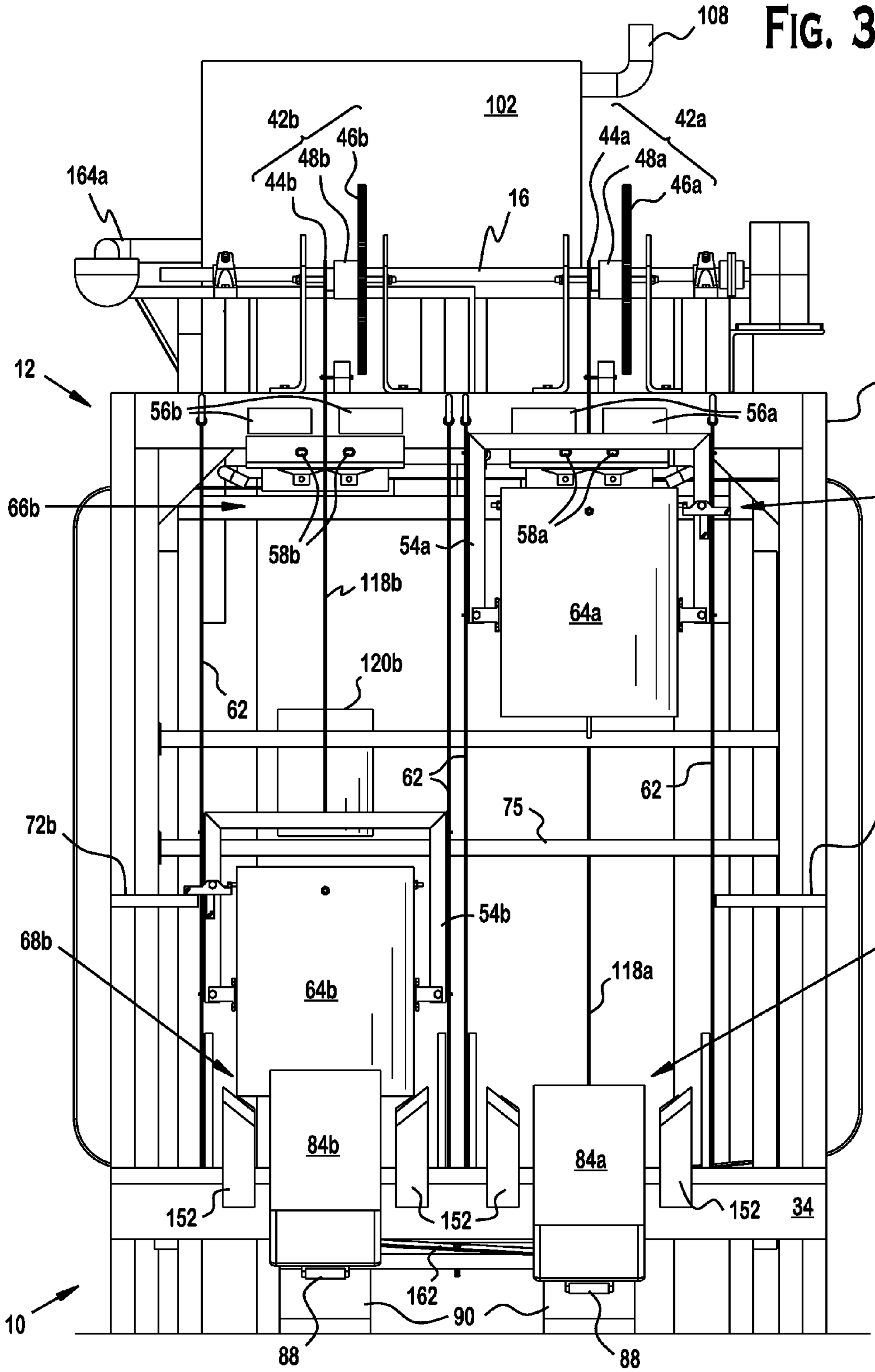
36

FIG. 2

FIG. 3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118b
64a
120b
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75
72b
72a
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118a
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162
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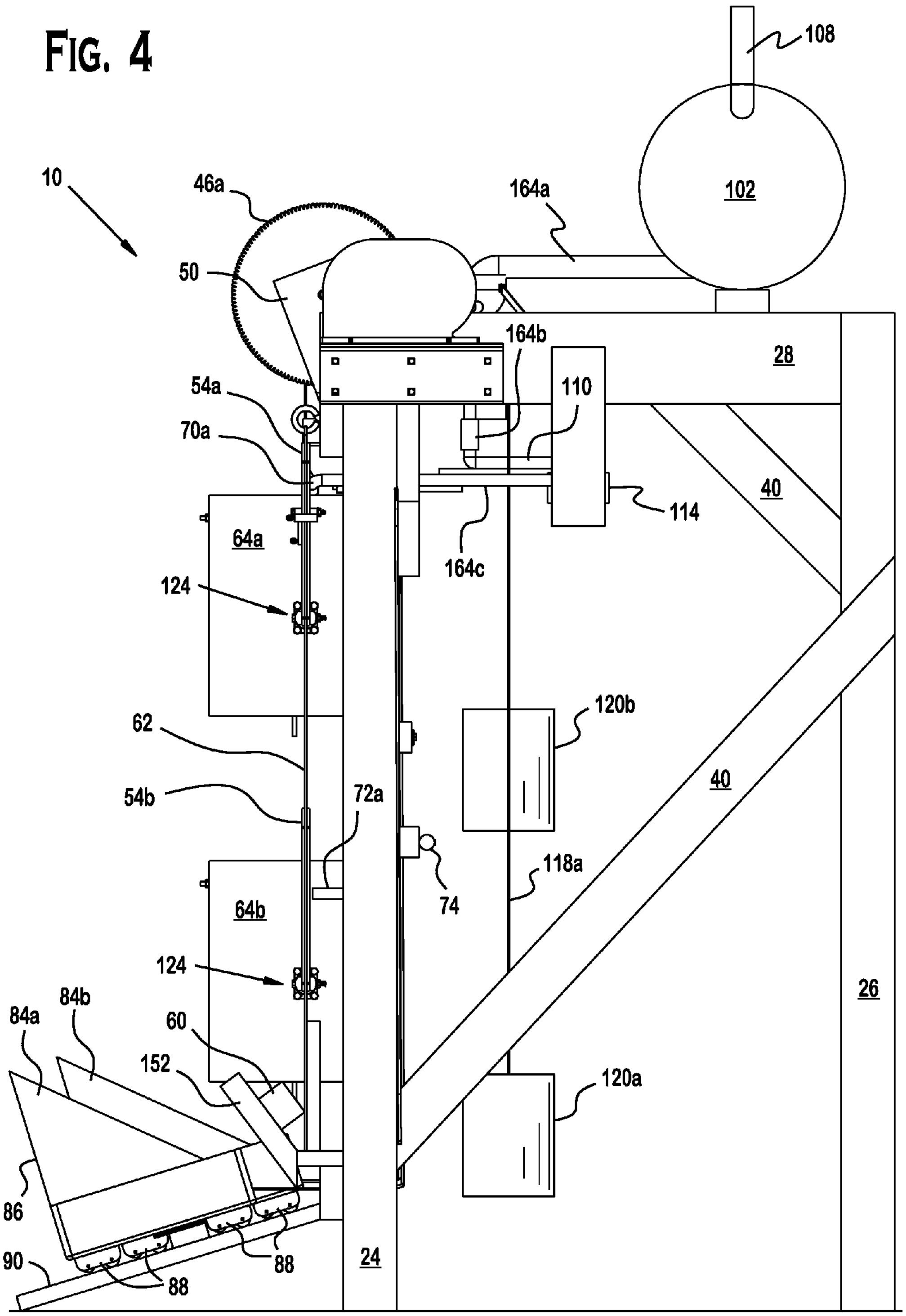
90
88
88

FIG. 4



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102
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40
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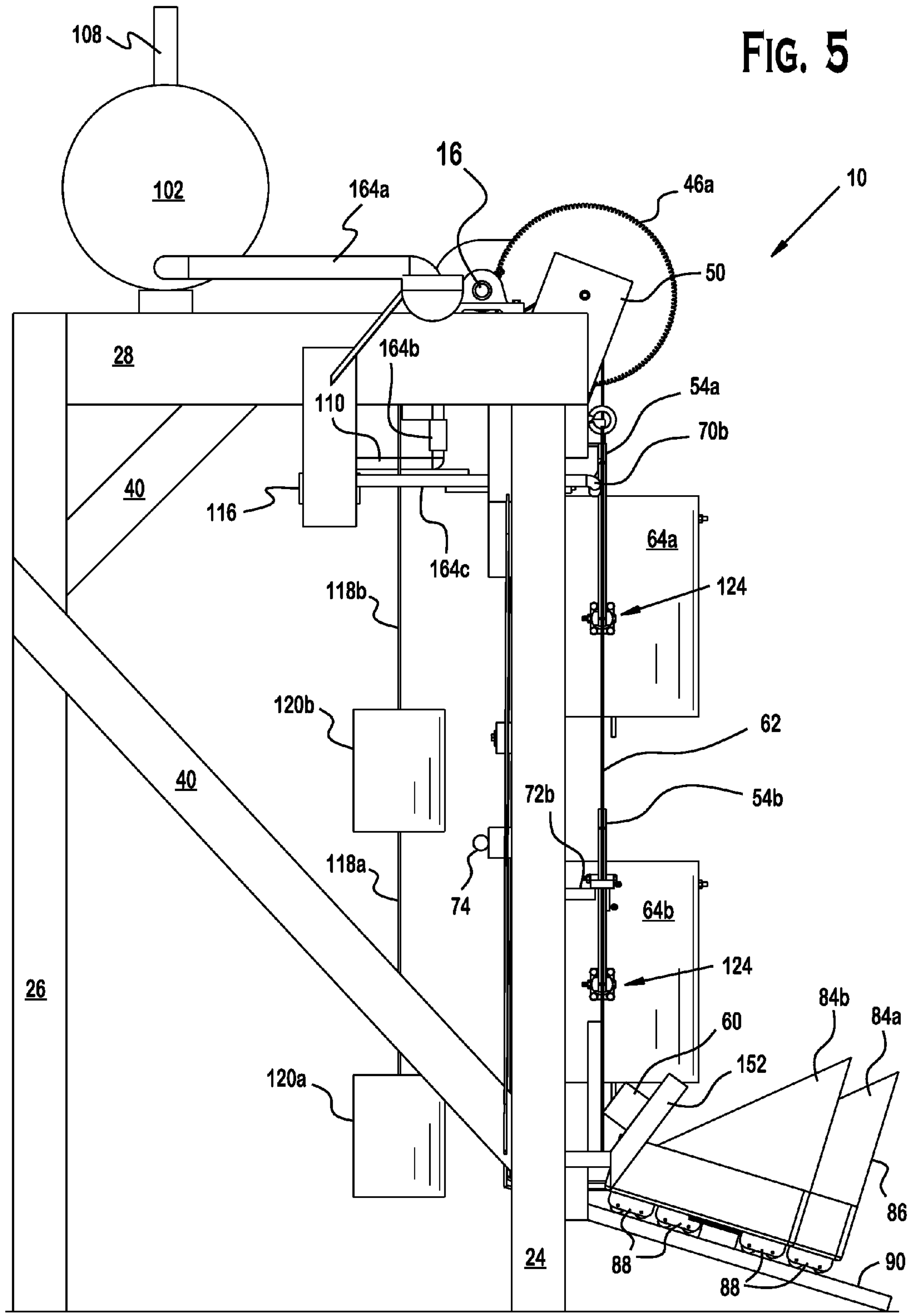
90
88
88
24

FIG. 5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120b
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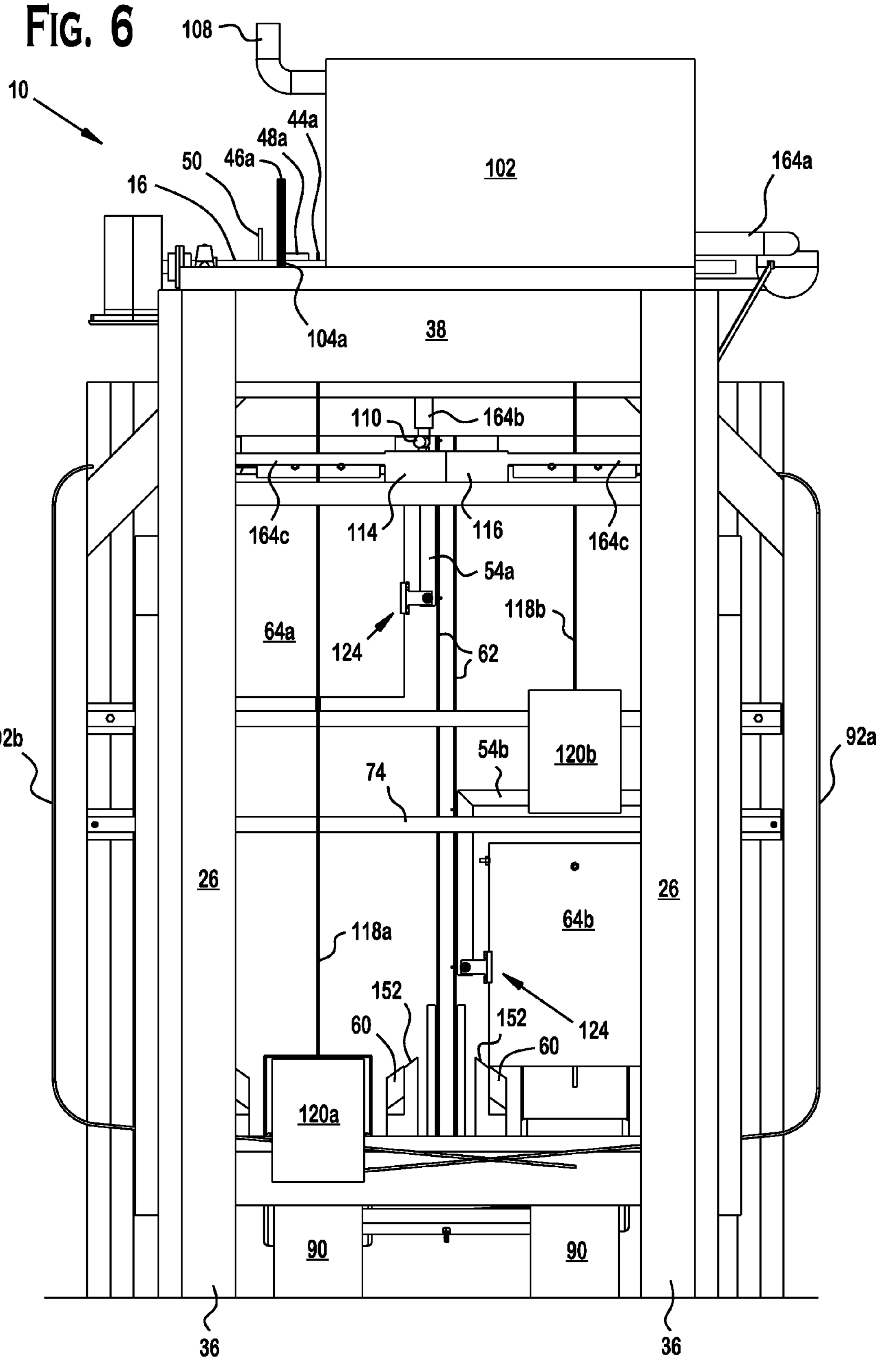
90

FIG. 6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36
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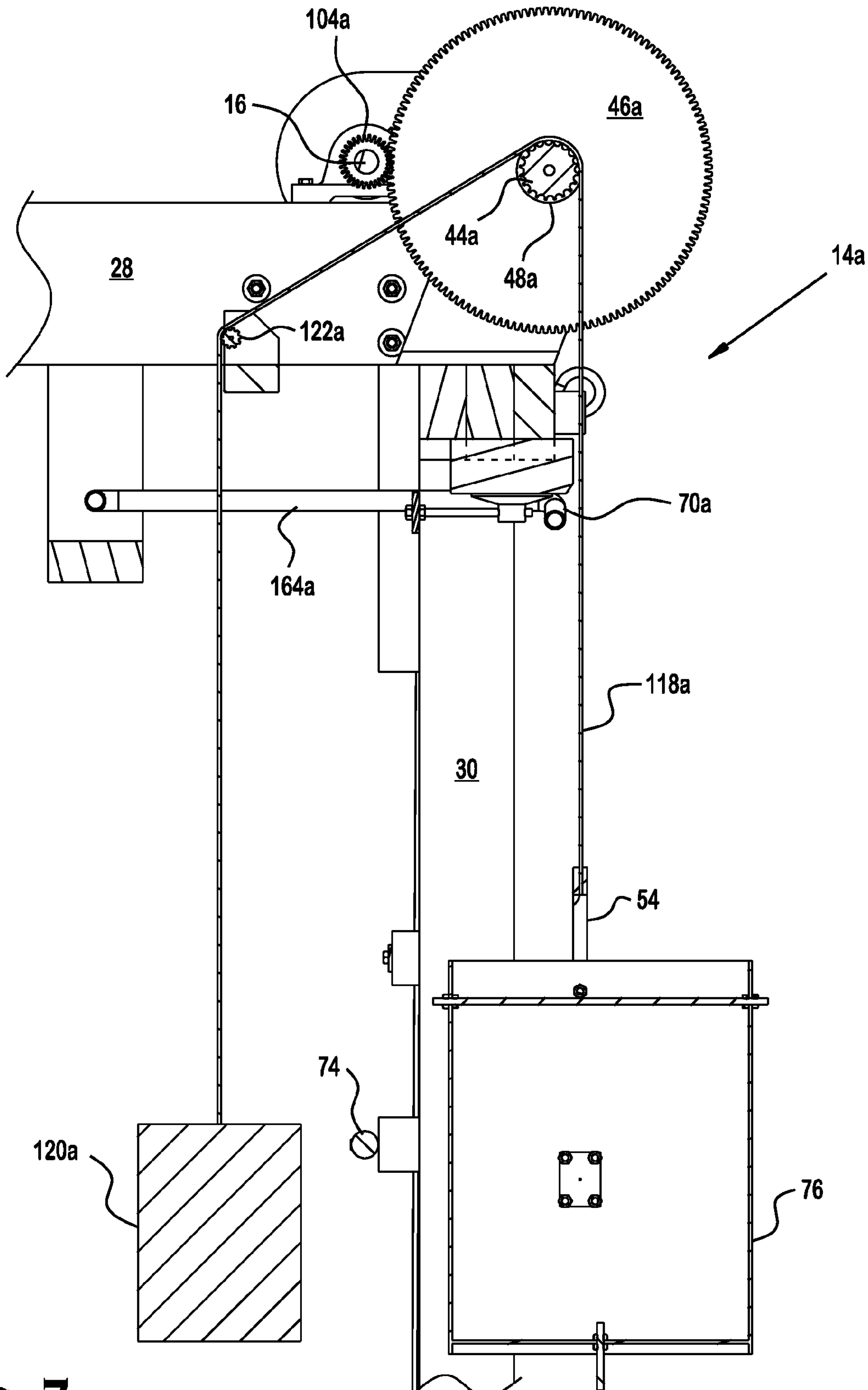

FIG. 7

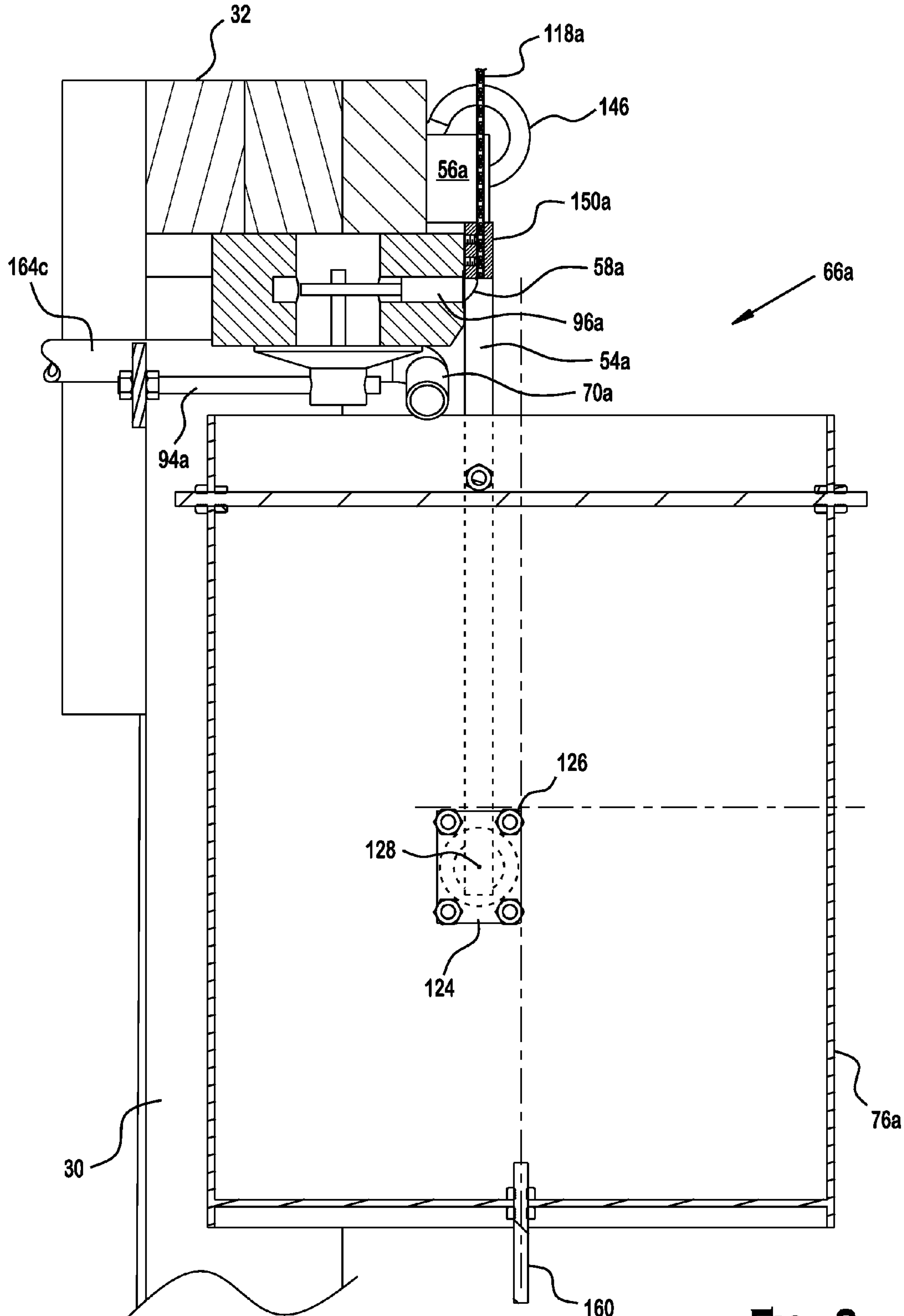
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FIG. 8

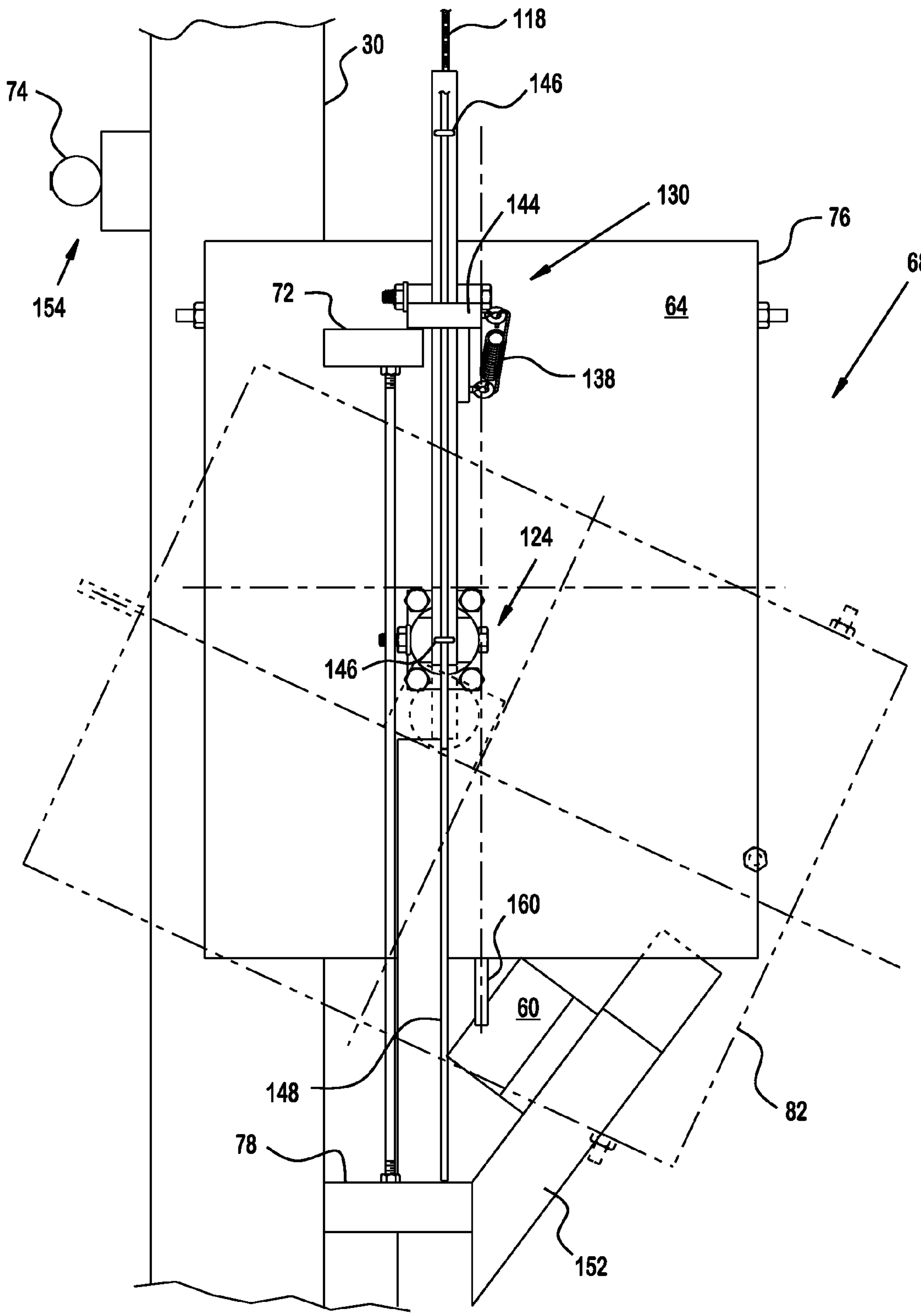
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FIG. 9

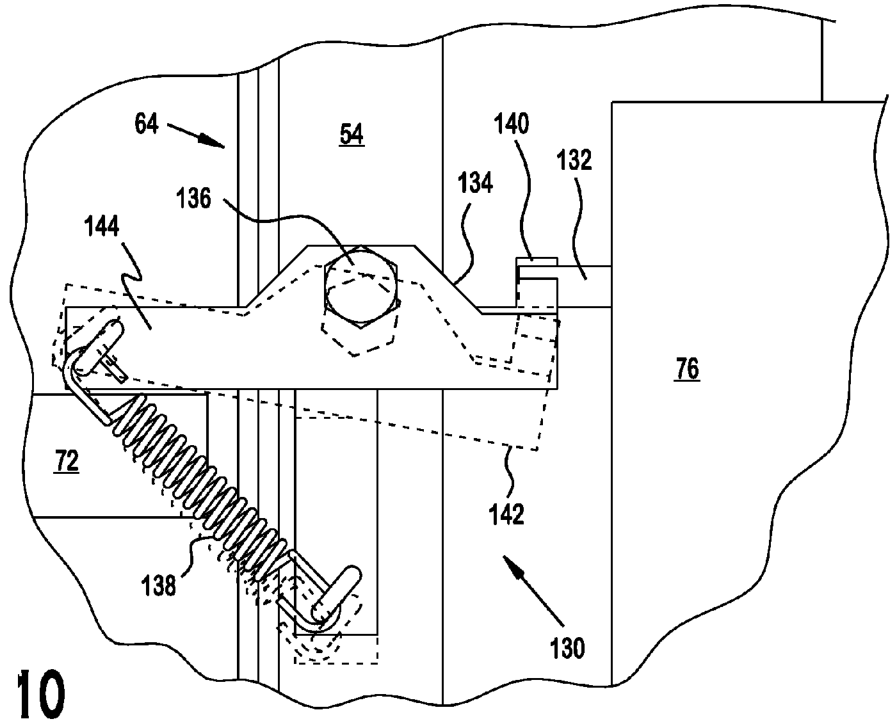
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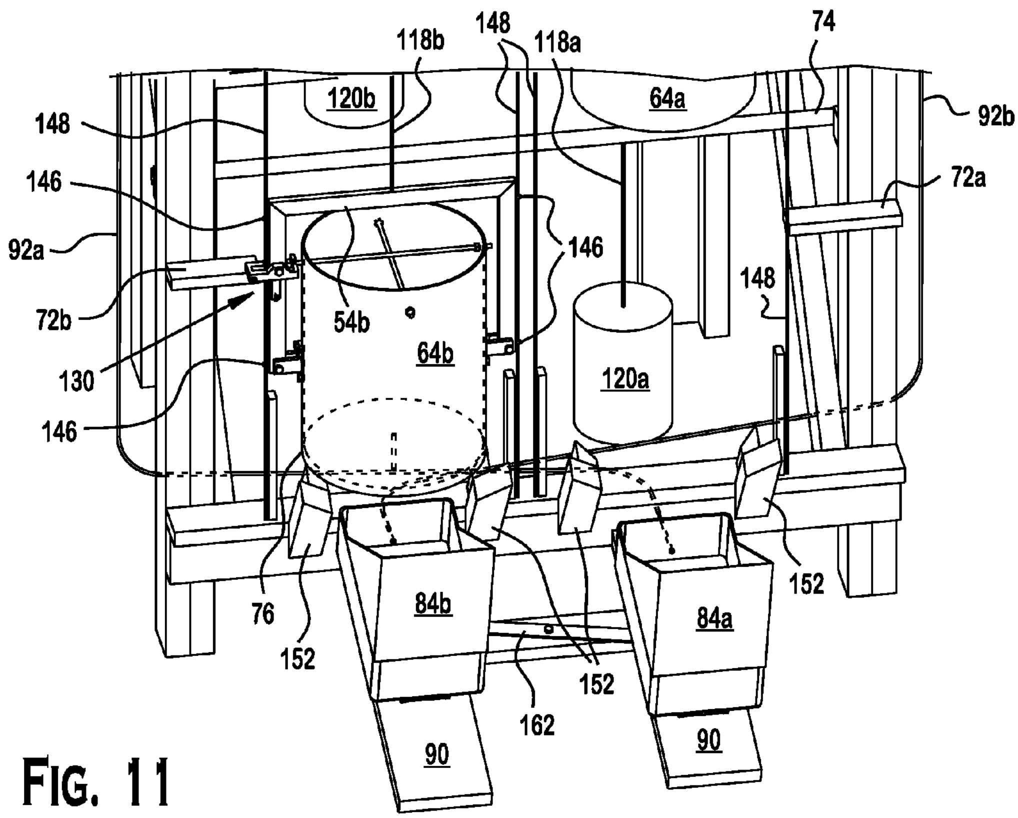
FIG. 10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152
162
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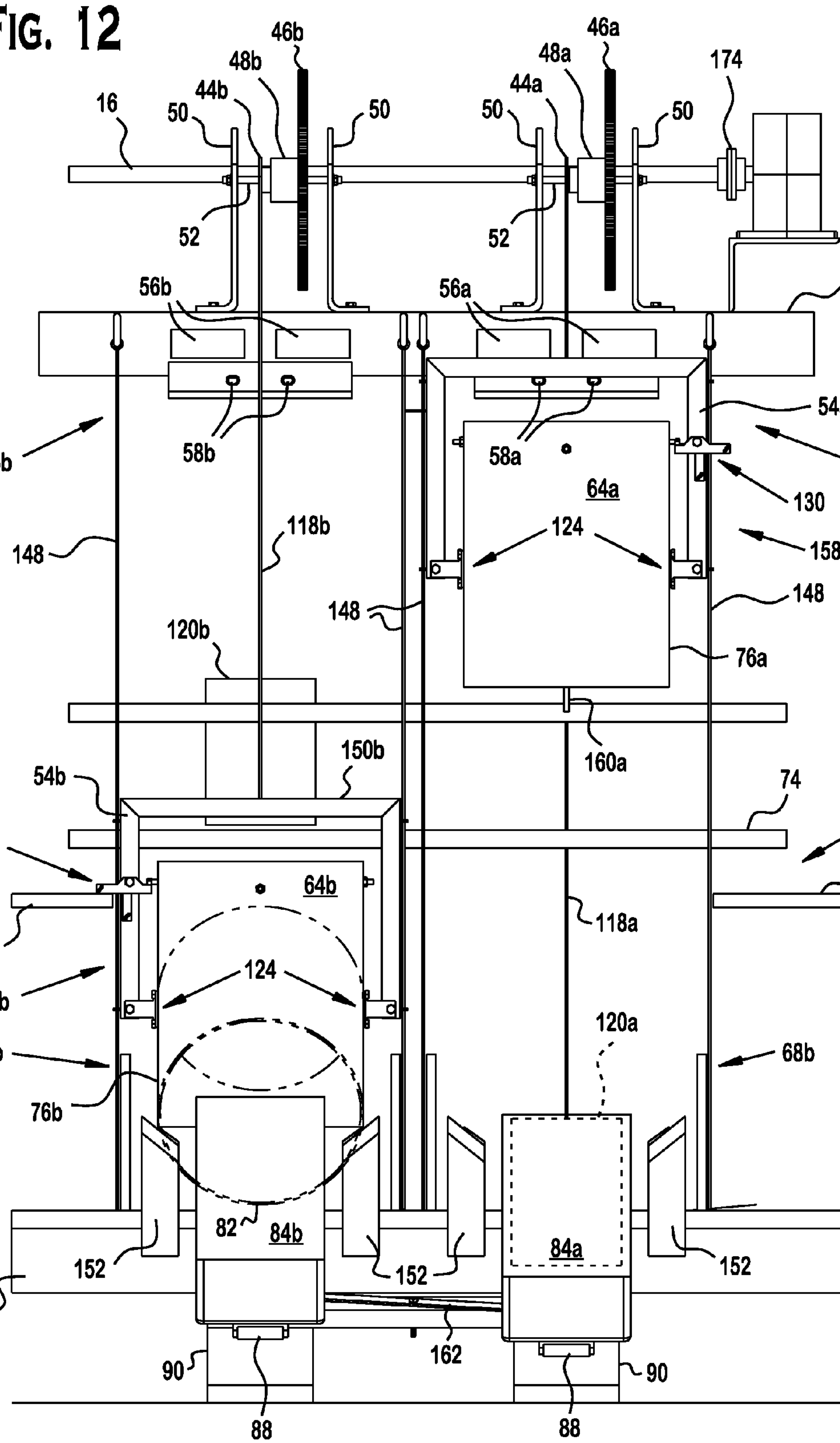
90

FIG. 11

FIG. 12



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66b
66a
64a
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118b
124
158a
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120b
76a
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54b
74
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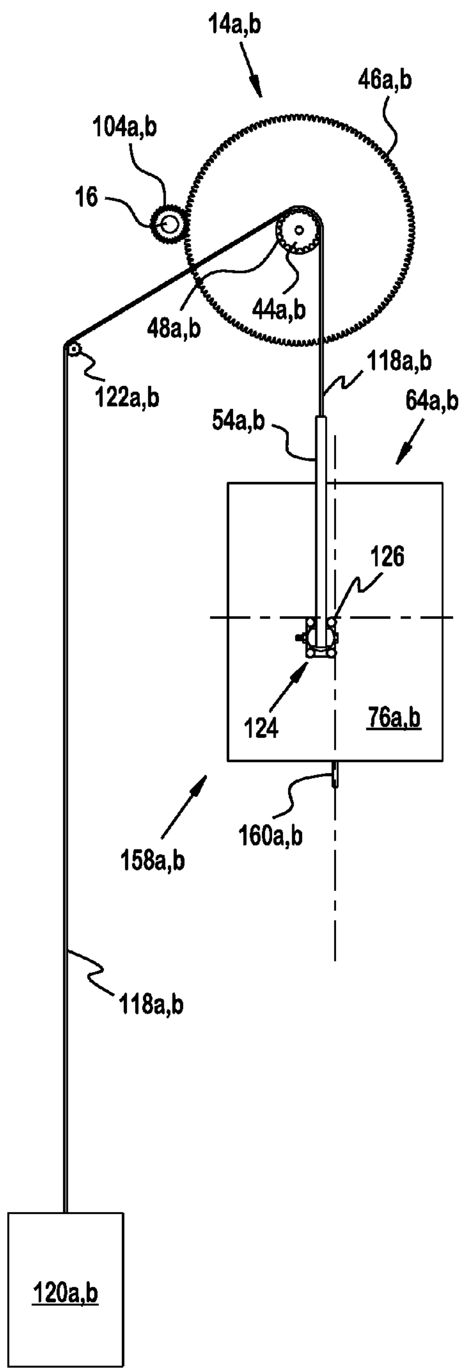
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FIG. 13

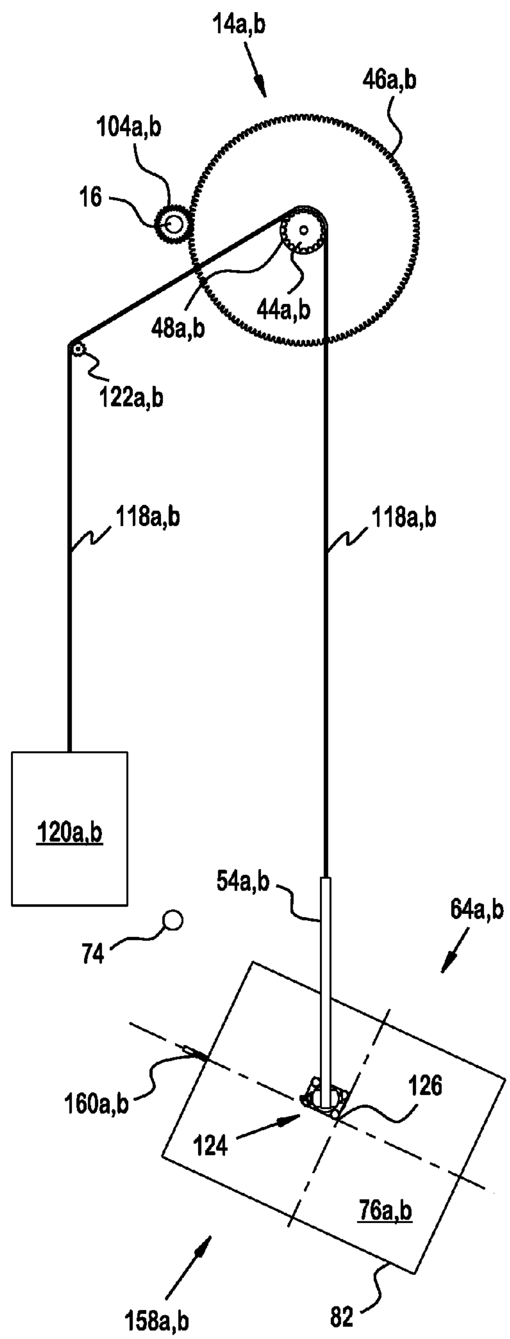
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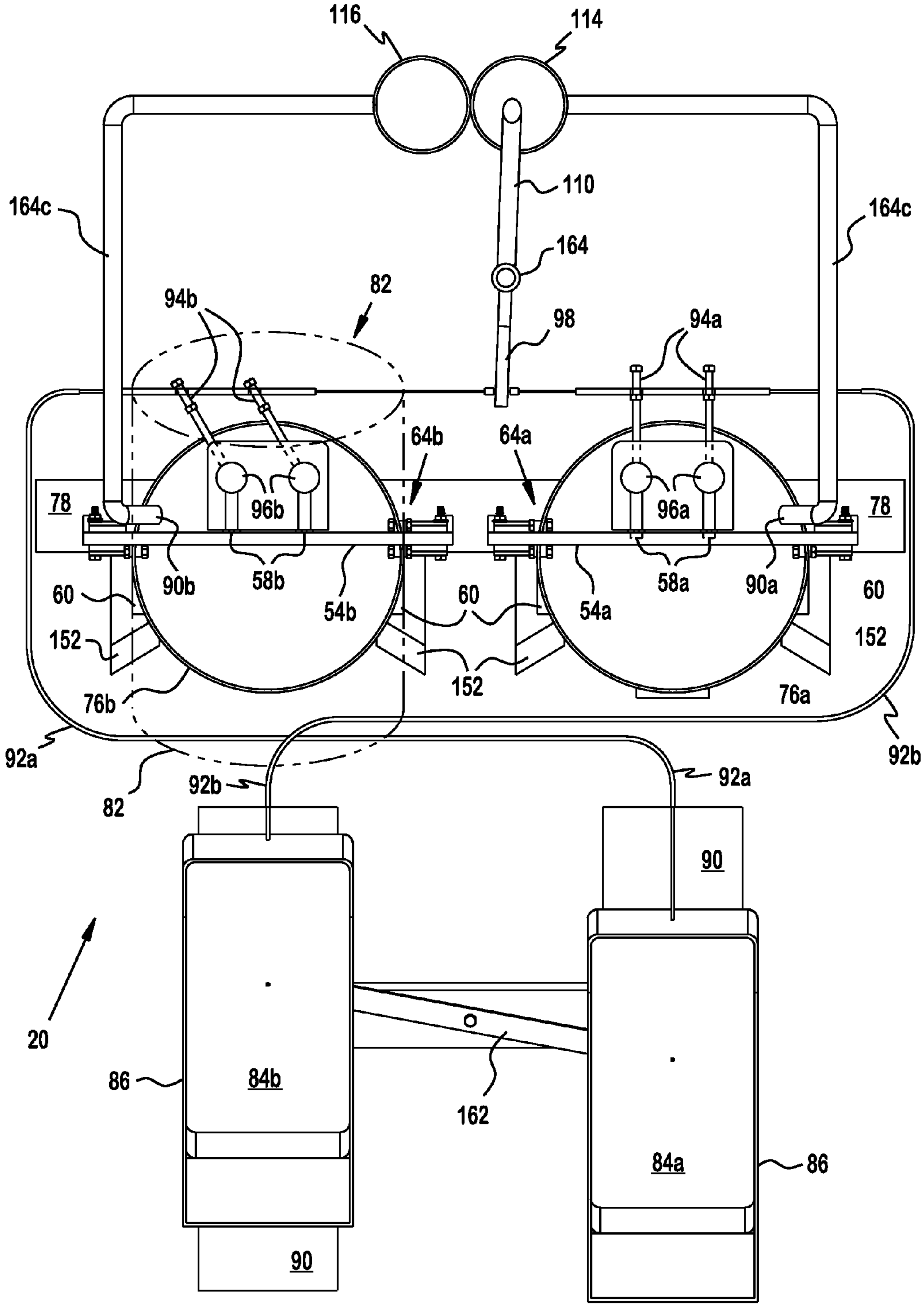
FIG. 14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90a
60
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152
152
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FIG. 15

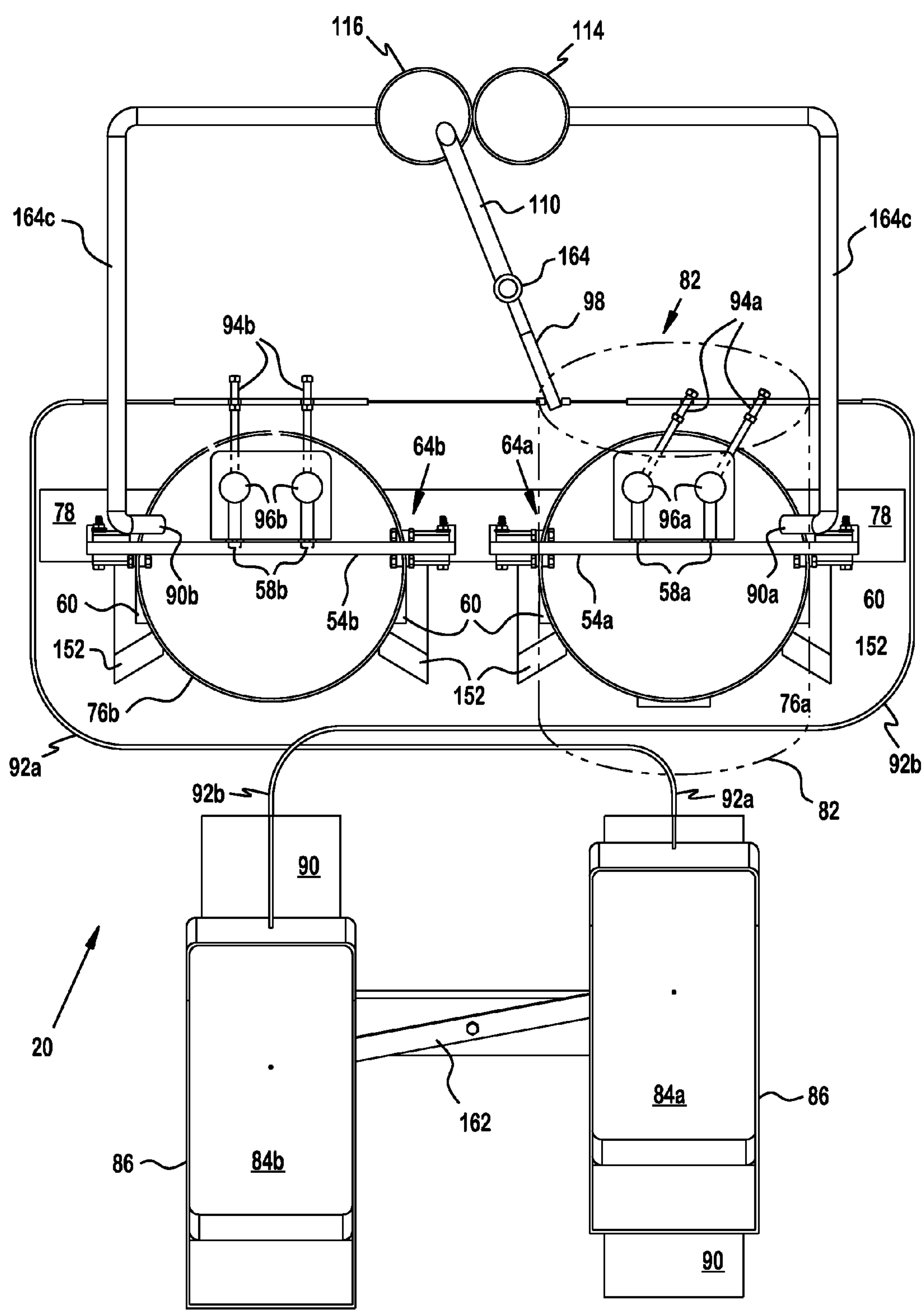
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FIG. 16

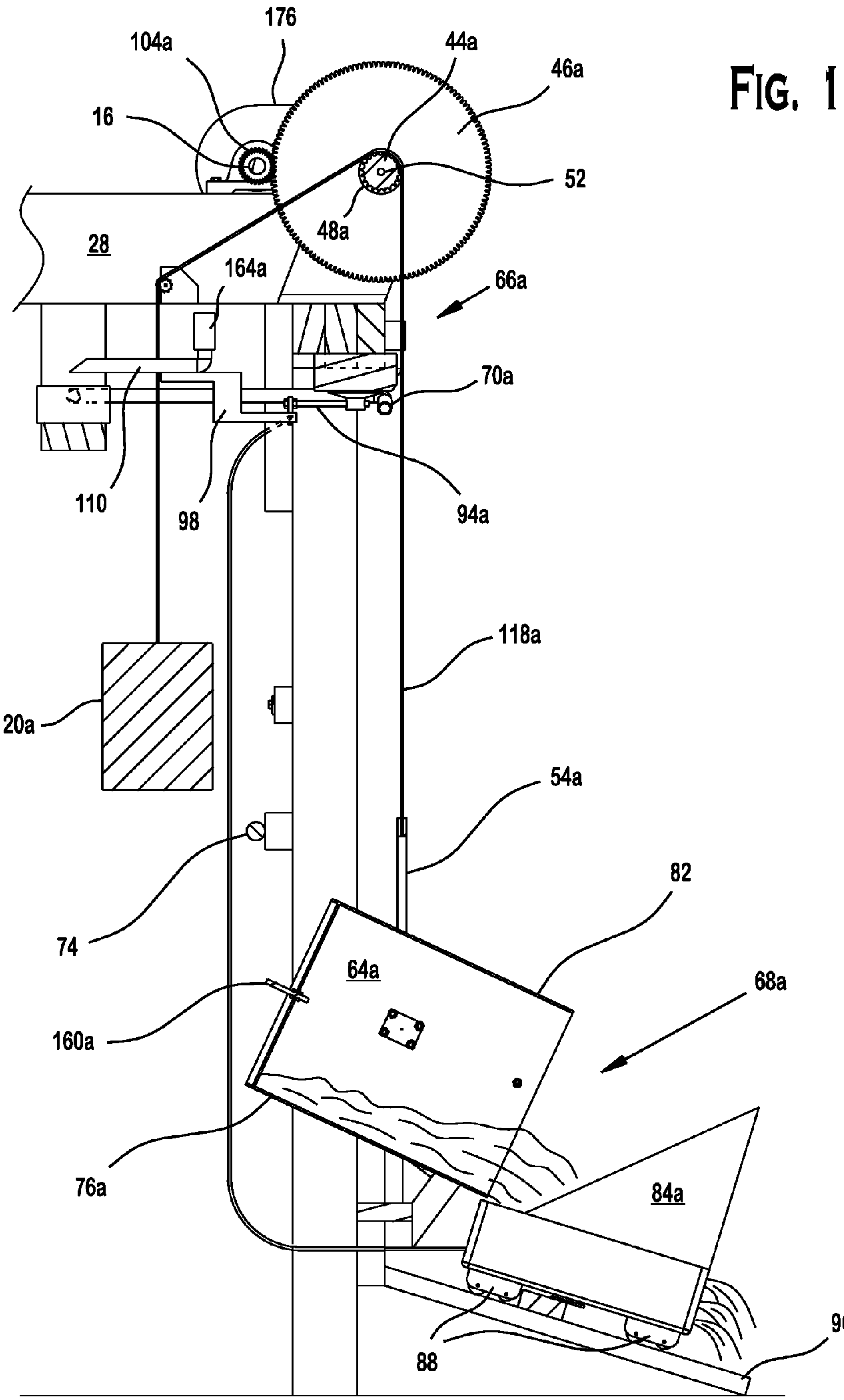
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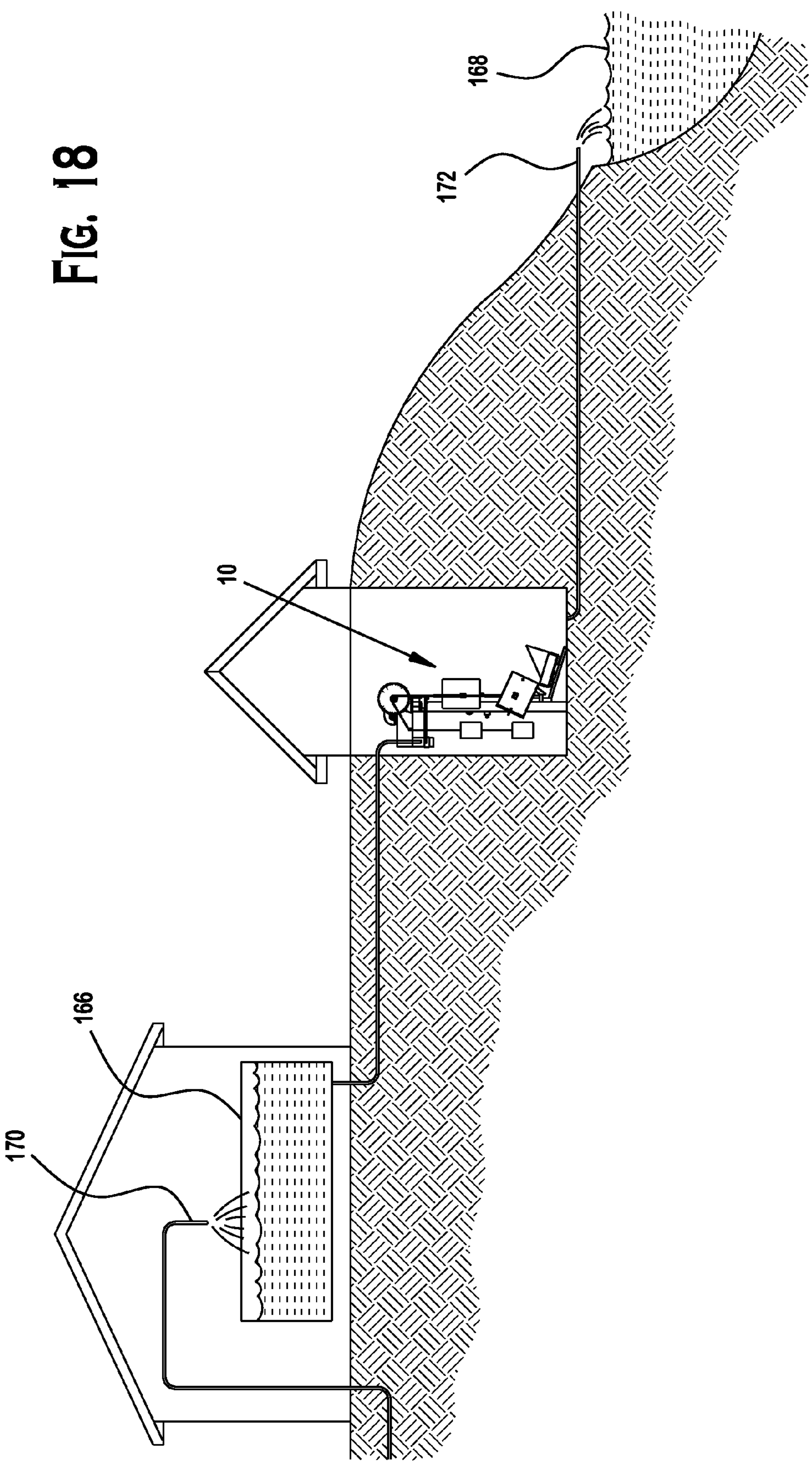
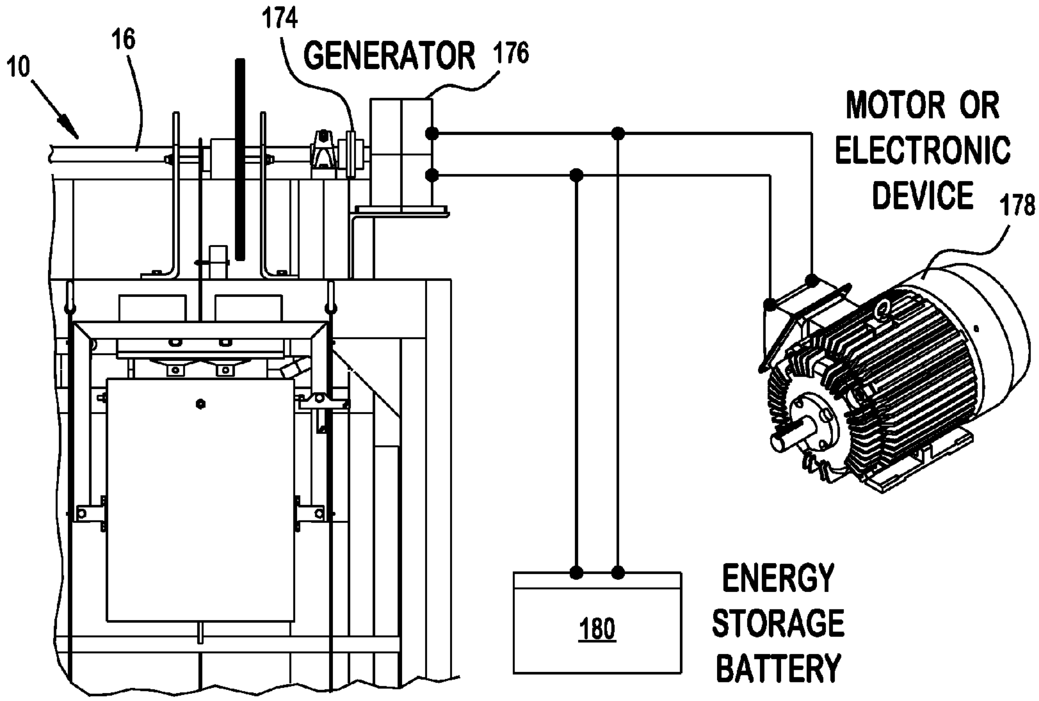
FIG. 17

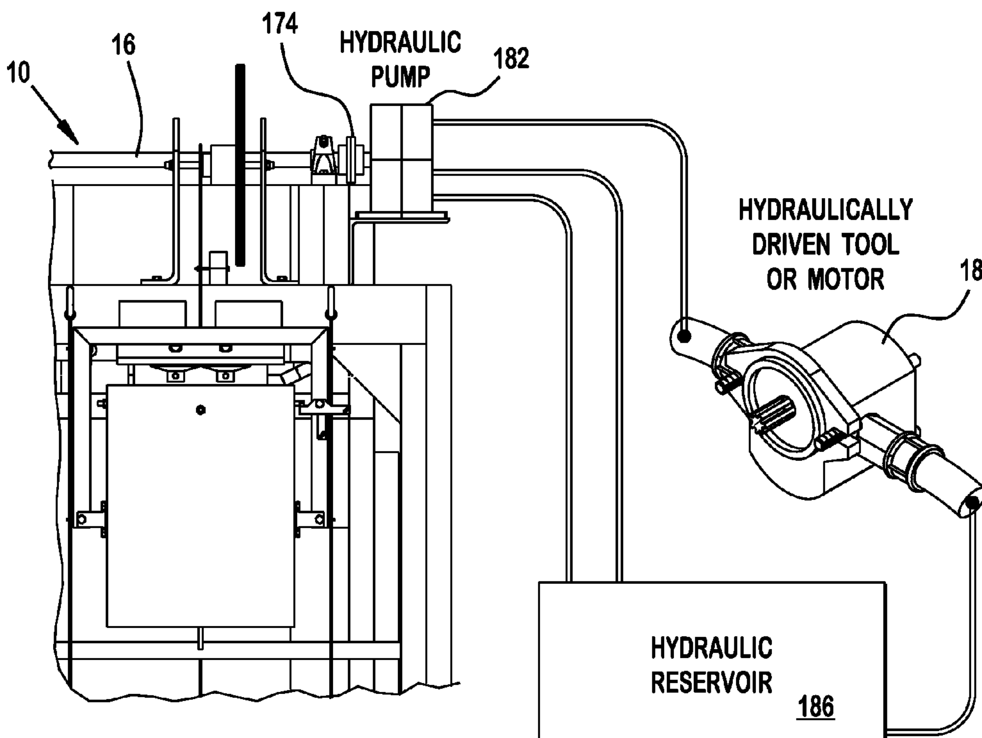
FIG. 18





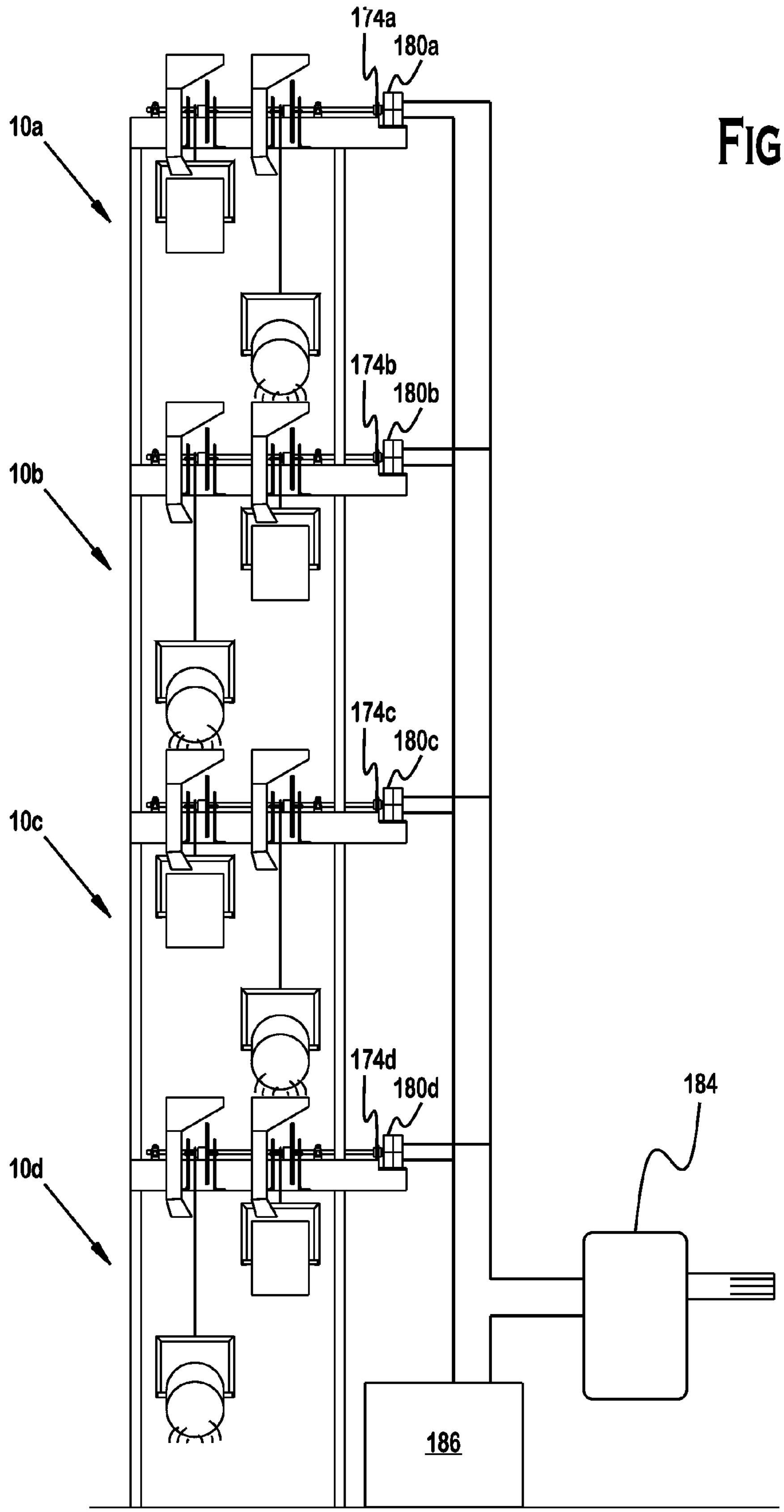
10
16
174
GENERATOR
176
MOTOR OR ELECTRONIC DEVICE
178
180
ENERGY STORAGE BATTERY

FIG. 19



10
16
174
HYDRAULIC PUMP
182
HYDRAULICALLY DRIVEN TOOL OR MOTOR
184
HYDRAULIC RESERVOIR
186

FIG. 20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10a
174b
180b
10b
174c
180c
10c
174d
180d
10d
184
186

FIG. 21

LOW FLOW POWER PLANT

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. patent application Ser. No. 61/597,506 filed on Feb. 10, 2012, the entire disclosure of which is incorporated by reference herein.

FIELD OF THE INVENTION

The present invention generally relates to a device and system for harnessing energy associated with fluids flowing from a low elevation potential. More particularly, this invention relates to an apparatus and method which is suitable for generating power from a water source characterized by relatively low total dynamic head.

BACKGROUND

Hydropower comes from converting energy in flowing water into useful mechanical power. This power may be converted into electricity using an electric generator or may be used directly to operate machines. In many hydropower systems there may be a head and a flow rate below which there is no advantage in trying to obtain power. Thus, a need exists for a hydropower plant that is operable under low flow conditions.

SUMMARY

The present invention relates to an apparatus and method for harnessing power from a source of working fluid. The apparatus may include a power shaft that includes a first end, a second end spaced from the first end, and a first power gear disposed between the first end and the second end. The apparatus may include a first reciprocating engine situated proximate to the power shaft and connected to the first power gear for delivering a power stroke. The first reciprocating engine may include a first bucket assembly. The first bucket assembly may include a first bucket mounting frame, a first bucket, a first connecting mechanism that connects the first bucket to the first bucket mounting frame to form a first hinge that pivots about a first pivot axis such that the first bucket creates a turning moment about the first pivot axis, and a first locking mechanism for selectively locking the first bucket in the first bucket mounting frame.

The apparatus, further, may include a first bucket filling station for filling the first bucket with working fluid. The first bucket filling station may include a first upper stop and a first lower stop, the first lower stop being selectively moveable between a first deployed position and a first retracted position. The first bucket filling station may further include a first lever for selectively retracting the first lower stop. The first lever being moveable between a first closed position and a first open position such that when the first lever is in the first closed position the first stop is in the first deployed position and when the first lever is in the first open position the first stop is in the first retracted position.

Also, the apparatus may include a working fluid distribution system for delivering working fluid to the first reciprocating engine. The working fluid distribution system may include a tank for storing working fluid, a first fill port in fluid communication with the tank, and a working fluid discharge system for discharging working fluid from the first reciprocating engine to complete the power stroke. Further still, the apparatus may include a first trip switch activator for releasing the first bucket assembly locking mechanism, and a control system for resetting the first reciprocating engine following completion of the power stroke.

In another aspect of the present invention, the first reciprocating engine may include a first counterweight, a first drive chain that comprises a first portion which is connected to the bucket assembly, a second portion which is connected to the first counterweight, and a third portion interconnecting the first portion and the second portion. Further still, the first reciprocating engine may include a first gear set which comprises a first ring gear in working contact with the first power gear for transmitting rotational motion to the power shaft.

In another aspect of the present invention, the first reciprocating engine further comprises a first positioning gear disposed between the first gear set and the first counter weight. The first gear set may include a first transmission gear in working contact with the third portion of the first drive chain, and a first ratcheting mechanism disposed between the first ring gear and first the transmission gear such that rotating the first transmission gear drives the first ring gear in the same direction and counter-rotating the first transmission gear does not affect rotation of the first ring gear.

In another aspect of the present invention, the apparatus may include a second power gear disposed on the power shaft between the first power gear and the second end. Furthermore, the apparatus may include a second reciprocating engine proximate to the power shaft which is connected to the second power gear. The second reciprocating engine may include a second bucket assembly, and a second gear set which comprises a second ring gear in working contact with the second power gear for transmitting rotational motion to the power shaft. The second reciprocating engine further may include a second counterweight and a second drive chain. The second drive chain may include a fourth portion connected to the second bucket assembly, a fifth portion connected to the second counterweight, and a sixth portion interconnecting the fourth portion and the fifth portion.

In another aspect of the present invention, the second reciprocating engine may further include a second transmission gear in working contact with the sixth portion of the second drive chain, and a second ratcheting mechanism disposed between the second ring gear and the second transmission gear such that rotation of the second transmission gear drives the second ring gear in the same direction and counter-rotation of the second transmission gear does not affect rotation of the second ring gear. The second reciprocating engine may further include a second positioning gear disposed between the second gear set and the second counter weight.

In another aspect of the present invention, the apparatus may include a second bucket filling station which includes a second upper stop, a second lower stop, the second lower stop being selectively moveable between a second deployed position and a second retracted position, and a second lever for selectively retracting the second lower stop which comprises a second closed position and a second open position such that when the second lever is positioned in a second closed position the second stop is in the second deployed position and when the second lever is in the second open position the first stop is in the second retracted position.

In another aspect of the present invention, the apparatus water distribution system may include an inflow structure in fluid communication with the tank for conveying working fluid to the apparatus, an outflow structure in fluid communication with the tank, a first drop basin situated hydraulically down gradient of the tank and located below a first target location, a second drop basin situated hydraulically down gradient of the tank and located below a second target location, a spigot in fluid communication with the outflow structure and disposed between the tank and the first and second drop basins such that the spigot is moveable from the first target location to the second target location. The water distribution system may further include a first fill port in fluid communication with the first drop basin which is situated above the first bucket assembly, and a second fill port in fluid communication with the second drop basin, which and situated above the second bucket assembly.

In another aspect of the present invention, the first locking mechanism may include a first strike secured to the first bucket, and a first catch, which comprises a first lever arm, and which is secured to the first bucket mounting frame, the first catch being movable between a first closed configuration such that the first strike is interlocked with the first catch to selectively lock the first bucket in the first bucket mounting frame, and a first open configuration such the first strike is not interlocked with the first catch, and the first catch is biased in the first closed configuration and oscillation of the first lever arm away from the first closed configuration positions the catch in the first open configuration.

In another aspect of the present invention, the first bucket mounting frame includes a plurality of guides to restrain movement of the bucket mounting frame, and the working fluid discharge system further includes a first pair of kick plates disposed below the first bucket assembly and a second pair of kick plates disposed below the second bucket assembly.

In another aspect of the present invention, the control system further may include a first ramp situated below the first pair of kick plates, a first water catch disposed on the first ramp, the first water catch being linked to the second lever such that movement of the first water catch down the first ramp causes the second lever to move to the second position, and causes the spigot to move to the first target location. The control system may further include a second ramp situated below the second pair of kick plates, a second water catch disposed on the first ramp, the first water catch being linked to the first lever such that movement of the second water catch down the second ramp causes the first lever to move to the second position, and causes the spigot to move to the second target location. Additionally, movement of the first water catch down the first ramp may cause the second water catch to move up the second ramp, and movement of the second water catch down the second ramp may cause the first water catch to move up the first ramp.

In another aspect of the invention, the apparatus may include a frame for supporting the first reciprocating engine. The first bucket may include a first kick and the frame may include a brace such that upward movement of the first bucket assembly away from the first pair of kick plates causes the brace to strike the first kick, rotating the first bucket into a vertical orientation and setting the first locking mechanism in the first closed configuration.

In another aspect of the present invention, the second end may be connected to a mechanical device such that rotation of the second end powers the mechanical device. The mechanical device may be a pump or a generator.

Also, the present invention relates to a method of harnessing power from a source of water. The method may include providing the apparatus of the present invention, connecting the source of water to the tank, filling the first bucket with water at the first bucket filling station, retracting the first lower stop to initiate a first power stroke, lowering the first bucket toward the first trip switch activator, rotating the first gear set to drive the first power gear and rotate the power shaft, releasing the first bucket assembly locking mechanism to complete the first power stroke, discharging water from the first reciprocating engine, securing the first bucket on the first lower stop, and powering a mechanical device which is connected to the power shaft.

In another aspect of the present invention, the method may include providing a second reciprocating engine, and operating the first and second reciprocating engines in lead lag operation to rotate the power shaft

DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate an embodiment of the invention, and together with the general description given above and the detailed description given below, serve to explain the features of the invention:

FIG. **1** is a front perspective view of a low flow power plant of the present invention;

FIG. **2** is a rear perspective view of the power plant of FIG. **1**;

FIG. **3** is a front view of the power plant of FIG. **1**;

FIG. **4** is a right side view of the power plant of FIG. **1**;

FIG. **5** is a left side view of the power plant of FIG. **1**;

FIG. **6** is a rear view of the power plant of FIG. **1**;

FIG. **7** is a partial section view of the power plant of FIG. **3**, showing the right side reciprocating engine about halfway through a power stroke;

FIG. **8** is a partial sectional view of the right side bucket assembly at the bucket filling station;

FIG. **9** is a side view of the left side bucket assembly at the bucket discharge station;

FIG. **10** is a front view of a bucket locking mechanism;

FIG. **11** is a front perspective view of the water discharge system;

FIG. **12** is a front view of one operational configuration of the power plant of FIG. **1** showing the right side bucket assembly at the bucket filling station and the left side bucket assembly at the bucket discharge station;

FIG. **13** is a side view of selected components of a reciprocating engine in the fill configuration;

FIG. **14** is a side view of selected components of a reciprocating engine in the discharge configuration;

FIG. **15** is a top view of the control system in the right side fill configuration;

FIG. **16** is a top view of the control system in the left side fill configuration;

FIG. **17** is a partial sectional view of a reciprocating engine discharging water at the bucket discharge station;

FIG. **18** is a schematic diagram of the power plant of FIG. **1** situated between a hatchery fish tank and a pond;

FIG. **19** is a schematic diagram of the power plant of FIG. **1** with a power take off connected to an electric generator that is used to power electrical equipment or devices;

FIG. **20** is a schematic diagram of the power plant of FIG. **1** with a power take off connected to a hydraulic pump that is used to operate a hydraulic drive system; and

FIG. **21** is a schematic diagram of multiple power plants of FIG. **1** with hydraulic pumps connected in series to drive the hydraulic motor.

DESCRIPTION

FIG. **1** depicts an exemplary embodiment of a power plant **10** of the present invention, which includes a frame **12**, two reciprocating engines **14** (herein after **14***a* (right side reciprocating engine), **14***b* (left side reciprocating engine)) a power shaft **16**, a water distribution system **18**, a water discharge system **20**, and a control system **22**.

As shown in FIG. **1**, the frame **12** may include a vertical front partition **24**, a vertical rear partition **26**, and a number of joists **28** that connect the front and rear partitions. The front partition **24** may include a pair of vertical members **30**, a header **32**, and a horizontal brace **34**. The rear partition **26** may include a pair of vertical members **36**, an upper horizontal member **38**, and a horizontal brace (not shown). The joist **28** may be spaced perpendicular to the front and rear vertical partitions. The joist may bear on the front partition **24** and may be hung on the rear partition **26**. The frame **12** may also include diagonal cross braces **40** to strengthen the structure. In the exemplary embodiment, the frame **12** is made from lumber. Although the frame may be constructed from wood, any suitable material, such as steel, may be used to construct the frame provided the material provides sufficient strength and support to the power plant. In the exemplary embodiment, the frame **12** has a height of approximately 60 inches, a width of approximately 46 inches, and a depth of approximately 38 inches.

The frame **12** may support the other components of the power plant. For example, the front partition **24** may support the reciprocating engines **14***a*, **14***b* the water discharge system **20**, and elements of the water distribution system **18** and control system **22**. Disposed at the top of the front partition are two gear sets (or gearings) **42***a*, **42***b* that form part of the reciprocating engines **14***a*, **14***b*, which drive the power plant **10**. Each gear set **42***a*, **42***b*, includes a transmission gear **44***a*, **44***b* a ring gear **46***a*, **46***b* and an intermediate ratcheting mechanism **48***a*, **48***b*. Each ring gear **46***a*, **46***b* and transmission gear **44***a*, **44***b* may be connected such that turning the transmission gear in one direction (e.g., clockwise) turns the associated ring gear in the same direction, but turning the transmission gear in the opposite direction (e.g., counterclockwise) does not. The teeth on each ring gear may be cut to transmit power. Each gear **42***a*, **42***b* set may be mounted between a pair of opposing steel flanges **50**. Each pair of steel flanges **50** may project forward from the front partition, and the axis **52** of each gear set may be positioned and secured by the flanges **50** such that the ring gear **46** set is above the front partition **24** and the forward facing side of the transmission gear **44***a*, **44***b* is vertically aligned with the bucket mounting frame **54**. In one embodiment, the transmission gear is a 4½ inch diameter steel sprocket and the ring gear is a 12 inch diameter cast iron power gear.

As shown in FIGS. **1**, **3**, **4** and **6**, the front partition **24** may support the working space (or track) of each reciprocating engine **14***a*, **14***b*. For example, the front partition **24** may include an upper stop **56***a*, **56***b*, a selectively moveable lower stop **58***a*, **58***b*, a discharge seat **60**, and guide wires **62**. Guide wires **62** may form a track that is positioned below a gear set **42***a*, **42***b* to constrain movement of the associated bucket assembly **64***a*, **64***b* along a generally linear path which traverses between an upper bucket filling station **66***a*, **66***b* and a lower bucket discharge station **68***a*, **68***b*. The front partition may further include a bucket fill port **70***a*, **70***b* proximate to each bucket filling station **66***a*, **66***b* and a trip switch activator **72***a*, **72***b* for unlatching the bucket assembly **64***a*, **64***b* at the discharge station **68***a*, **68***b*, as well as a horizontal brace **74** for re-latching the bucket **76***a*, **76***b* into a vertical orientation within the bucket assembly **64***a*, **64***b* during recoil.

The front partition **24** may support (or include) water discharge stations **68***a*, **68***b*. Each water discharge station **68***a*, **68***b* may be attached to a horizontal brace (or strap) **34** that is positioned several inches above the base of the frame. The horizontal brace may include an upper ledge **78** that supports the discharge seat **60** and angled kick plates **80**, which assist in pivoting the bucket **76***a*, **76***b* into the discharge position **82** (FIGS. **14** and **17**). The water discharge station further may include a pair of sieves (or water catches) **84***a*, **84***b*. Each water catch **84***a*, **84***b* may be a container **86** that is mounted on a set of rollers **88** (FIG. **17**). The rollers **88** may be disposed on a ramp **90** that slopes downward and away from the upper ledge **78**. The ramp **90** may have a slope of approximately 0.3 ft/ft, as the ramp in the disclosed embodiment rises 5½ inches over a horizontal distance of 19 inches.

Referring to FIGS. **15** and **16**, the water catches **84***a*, **84***b* may be connected by an elongate member **162** that is free to pivot about a point approximately midway between the water catches. Additionally, a steel cable **92***a* enclosed with a brake line hose may connect the right water catch **84***a* to the left selectively moveable lower stop **58***b*. Similarly, another steel cable **92***b* enclosed within another brake line hose may connect the left water catch **84***b* to the right selectively moveable lower stop **58***a*. The cables **92***a*, **92***b* may be threaded through holes or eyelets on the front partition members (not shown). In the exemplary embodiment, the cables are three sixteenth inch (3⁄16") diameter, steel, brake line cables. More specifically, the cables **92***a*, **92***b* may be connected to lever handles **94***a*, **94***b* of the respective latch bolts that serve as the selectively moveable lower stops **58***a*, **58***b*. Additionally, the handles **94***a*, **94***b* may be interconnected to form a closed mechanical control circuit. A lever **98** from the water distribution system, which is secured to the water spigot, may be further connected to the closed mechanical control circuit.

Referring to FIG. **1**, the joists may support the power shaft **16**, power receiving equipment **100** (e.g., an electrical generator or hydraulic pump), the equalization tank **102**, and elements of the water distribution and control systems. The power shaft **16** may be disposed on the top of the ceiling joist. The power shaft may be secured within mounting brackets that are fixed to the ceiling joists. In the exemplary embodiment, the power shaft is made from steel and has a diameter of approximately seven eighths of an inch (7⁄8"). The power shaft may include two power gears **104***a*, **104***b* that each mesh with one of the ring gears **46***a*, **46***b* on the front partition. The power gears **104***a*, **104***b* and ring gears **46***a*, **46***b* being interconnected such that rotation of one ring gear causes the power shaft **16** to rotate. In the exemplary embodiment, the power gears are two inch diameter steel gears. One end portion of the power shaft may form a power take off for operating external equipment or loads. The power take off may possess a non circular cross section such that the power shaft may be able to deliver greater torque to connected equipment that may be mounted and secured on the joists. For instance, without limitation, the connected equipment **100** may be an electrical generator or a hydraulic pump.

Referring to FIGS. **4** and **5**, the joists may be used to support the equalization tank **102**. The equalization tank (e.g., a fifteen gallon capacity plastic container) may be positioned to receive influent water (or the working fluid) from a water supply via inflow port **108**. An outflow port **106** of the equalization tank may be disposed below the inflow port **108** and connected hydraulically to a central water distribution spigot **110**. Referring to FIGS. **6**, **15** and **16**, piping and fittings **164***a* may connect the outflow port **106** to a spigot feed drop basin **112**. Additional fittings and piping **164***b* may connect the spigot feed drop basin **112** to the spigot **110** which may be secured to the joist. The spigot **110** may be disposed above (and movable between) a right side drop basin **114** and a left side drop basin **116**. These drop basins may be disposed on a beam hung from the ceiling joists. Additional piping and fittings **164**c may be used to hydraulically connect the right and left side drop basins **114**, **116**, to the right and left side fill ports **70**a, **70**b, respectively.

Referring to FIGS. **1** and **3**, the power plant **10** may include two reciprocating engines **14**a, **14**b, each of which may be substantially identical to the other. Each reciprocating engine **14**a, **14**b, may possess a gear set **42**a, **42**b, a bucket mounting frame (or horse shoe bracket) **54**a, **54**b, a bucket (or similar container) **76**a, **76**b, a drive chain **118**a, **118**b, and a counterweight **120**a, **120**b. The gear set **42**a, **42**b of each reciprocating engine **14**a, **14**b may be positioned adjacent to the power shaft **16** atop the power plant frame **12**. As shown in FIG. **17**, one end of the drive chain **118**a may be connected to the bucket mounting frame **54**a, and the opposite end of the drive chain may be connected to the counterweight **120**a. The drive chain **118**a may be drawn over the transmission gear (or bucket gear) **44**a, and a counter weight positioning gear **122**a. In one embodiment, the drive chain **118**a is a bicycle chain, the transmission gear **44**a is an approximately four inch diameter sprocket on a ten speed bicycle cog set, and the counter weight positioning gear **122**a is a bicycle rear derailleur. Additionally, the bucket **76**a may be sized such that when it is nearly full of water, it is sufficiently heavy to pull the drive chain **118**a about the transmission gear **44**a and raise the counterweight **120**a as it descends from the bucket filling station **66**a located near the top of the frame to a bucket discharge station **68**a located near the base of the frame. The counterweight **120**a may be sufficiently heavy such that it quickly, reliably, and smoothly raises the empty bucket assembly **64**a from the bucket discharge station **68**a to the bucket fill station **66**a. In the exemplary embodiment, the power shaft **16** and the gear set **42**a is approximately five feet from the ground, the bucket **76**a is a five-gallon bucket, the counterweight **120**a is a nail container filled with approximately six pounds (5 lbs. 13 oz.) of gravel, and the recoil of the empty bucket assembly **64**a from the bucket discharge station **68** to the bucket fill station **66** is completed in approximately two seconds.

Additionally, the transmission gear **44**a may be connected to a ring gear **46**a. The ring gear **46**a may have a diameter greater than the transmission gear **44**a. The circumference of the ring gear may be cut to form a power gear. The ring gear **46**a may be connected to the transmission gear **44**a such that the ring gear and the transmission gear rotate about a common axis **52**. Moreover, the ring gear **46**a and the transmission gear **44**a may be connected such that turning the transmission gear **44**a in one direction (e.g., clockwise) turns the ring gear **46**a in the same direction, but turning the transmission gear **44**a in the opposite direction (counter-clockwise) does not. For example, the transmission gear **44**a may form a free wheel (also known as a block), which possess a single sprocket (or a set of sprockets) mounted on a body that contains an internal ratcheting mechanism **48**a and mounts on a threaded hub of the ring gear **46**a. Referring to FIG. **1**, the transmission gears **44**a, **44**b may be a free wheel from a ten speed bicycle. The gear sets **42**a, **42**b of the reciprocating engines **14**a, **14**b may be modified to accommodate differing operating conditions. For instance, certain applications may require the availability of multiple gear ratios, and thus the transmission may include a gear box or similar mechanism to selectively control the overall gear ratio for the power plant transmission over a range of gear ratios. For example, the range of gear ratios may be selected from gear ratios ranging from about 0.1:1 to 100:1.

As shown in FIGS. **1** and **3**, the bucket mounting frame **54**a, **54**b may be secured to the bucket **76**a, **76**b by a connecting mechanism **124** such that the connecting mechanism forms a swivel joint between the bucket mounting frame **54**a, **54**b and the bucket **76**a, **76**b. For example, two connecting mechanisms **124** may lay along an axis perpendicular to the longitudinal axis of the bucket mounting frame **54**a, **54**b such that the bucket and the bucket mounting frame form a hinge. As shown, in FIG. **8**, the connecting mechanism may be located below the center of gravity **126** of the bucket **76**. The connecting mechanism **124** may be offset from the vertical center line of the bucket so that the center of gravity of the bucket **126** creates a tipping moment about the pivot axis **128** of the hinge (see also, FIGS. **13** and **14**).

Referring to FIG. **10**, the bucket mounting frame **54** includes a locking mechanism **130** for selectively locking the bucket in a vertical configuration. For example, the locking mechanism **130** may be a latch. In the exemplary embodiment, a strike **132** is secured to the bucket **76** and a catch **134** is secured to the bucket mounting frame **54**. The catch **134** may be connected to the bucket mounting frame **54** such that the catch **134** oscillates about a trip switch pivot **136**. The catch **134** may be biased with a resilient member (e.g., coil spring) **138** in a closed configuration **140** such that one end of the catch is interposed against (or interlocked with) the strike **132** and another portion of the catch **144** projects outwardly from the bucket mounting frame **54** to form a lever arm. To release the latch **130** from the closed configuration **140**, a trip switch activator **72**, which may be a static member, pushes against the lever arm **144** upward as the bucket **76** descends, causing the lever arm **144** to rotate about the trip switch pivot **136** and separate the catch **134** from the strike **132**. This leaves the bucket **76** free to rotate about the pivot axis **128** of the connecting mechanism **124**. As described above in connection with FIG. **9**, the pivot axis **128** may be located such that the weight of the bucket **76** creates a movement about the pivot axis to facilitate tipping of the bucket and the release of water at the bucket discharge station **68**.

Referring to FIG. **11**, the side of the bucket mounting frame **54**b may include screws with a looped head **146**. Four guide wires **148** may extend from the ledge **78** to the top of the frame **12** (not shown). The guide wires **148** may pass through the looped head screws **146** to provide a working area (or track), which restrains movement of the bucket mounting frame **54**.

Referring to FIG. **8**, the bucket mounting frame (or horseshoe bracket) **54**a of the reciprocating engine **14**a may be secured in the bucket filing station (or top position) **66**a by a static upper stop **56**a and a selectively movable lower stop **58**a on the power plant frame **12**. The selectively movable lower stop **58**a may be formed from a latch bolt **96**a. The latch bolt **96**a may be a spring loaded bolt with an angled edge. In the exemplary embodiment, the cross member **150** of the bucket mounting frame **54**a rests on top of the flat edge of two latch bolts **58**a. Each latch bolt may be a latch bolt from a door lock. Each latch bolt may be retracted by rotating a lever **94**a in the same manner as turning a door knob.

Referring to FIG. **9** the trip switch activator **72** may be positioned below the lever arm **144** of the locking mechanism **130**. Referring to FIG. **10**, as the bucket assembly **64** descends, the lever arm **144** contacts the trip switch activator **72** pushing the lever arm **144** up and releasing the strike **132**. Referring to FIG. **9**, although the trip switch activator **72** may be a stop (or a block on a threaded rod) any suitable device may be used to release the locking mechanism **130** provided the device releases the locking mechanism **130** as the bucket assembly **64** arrives at the bucket discharge station **68**. The height of the trip switch activator **72** may be adjustable to allow adjustment of the location and timing at which the locking mechanism **130** is released to discharge water from the bucket. In addition, angled static members (or kick plates)

152 may be positioned on the discharge side of the bucket to push the bucket **76** about the pivot **128** (FIG. **8**) as the bucket descends to the bucket discharge station **68**. To guide the motion and extent of bucket repositioning at the bucket discharge station **68**, kick plates **152** may be located on opposite sides of the bucket **76**.

Referring to FIGS. **12-14**, each reciprocating engine **14***a*, **14***b*, includes a bucket recoil mechanism **154***a*, **154***b*, which automatically moves the bucket assembly **64***a*, **64***b* from the discharge configuration **156***a*, **156***b* into the fill configuration **158***a*, **158***b*. As shown in FIGS. **9** and **14**, a longitudinal member **160***a*, **160***b* extends from the bottom of the bucket **76***a*, **76***b*. In the exemplary embodiment, the longitudinal member **160***a*, **160***b* is a threaded steel rod approximately 1¼ inches in length. The longitudinal member may be configured and dimensioned to encounter the horizontal brace **74** of the frame **12**. Preferably, the recoil rate of the bucket assembly **64***a*, **64***b* is sufficient to cause the impact to the longitudinal member (or bucket kick) **160***a*, **160***b* from the horizontal brace **74** to create a moment about the bucket pivot **128** that is sufficient to swing the bucket **76***a*, **76***b* into a vertical position and secure the bucket **76***a*, **76***b* in the locking mechanism **130** of the bucket assembly **64***a*, **64***b*.

Referring to FIGS. **15** and **16**, the water distribution system may include a fifteen gallon tank (not shown), an L-shaped spigot **110**, a right side drop basin **114**, a left side drop basin **116**, and associated piping and fittings **164***c* for conveying water under gravity flow from the right and left side drop basins **114**, **116** to each respective bucket fill port **90***a*, **90***b*. As shown in FIG. **1**, tank **102** may have a water supply port **108** and may receive the external water supply. The tank may be sized to equalize the flow rate to the power plant. The tank **102** may be hydraulically connected to the spigot **110**. Referring to FIGS. **15** and **16**, the spigot **110** may be free to rotate from a first position over the right side drop basin **114** (FIG. **15**.) and a second position over the left side drop basin **116** (FIG. **16**). The spigot **110** may be connected to a lever arm **98** such that when the lever arm swings toward the right side drop basin, the spigot is positioned over the left side drop basin. Moreover, when the lever arm swings toward the left side drop basin, the spigot may be positioned over the right side drop basin. The piping and fittings from the right side drop basin **114** are configured and dimensioned to convey water to a right side bucket fill port **90***a*. The piping and fittings from the left side drop basin **116** are configured and dimensioned to convey water to the left side bucket fill port **90***b*.

Additionally, the power plant **10** may include a water discharge system **20**. Referring to FIGS. **15-17**, each reciprocating engine **14***a*, **14***b* discharges water from the bucket **76***a*, **76***b* to a sieve (or water catch) **84***a*, **84***b*. The water catch **84***a*, **84***b* is a container **86** that is mounted on a set of rollers **88** (FIG. **17**). The rollers **88** are disposed on a ramp **90** which slopes away from the base of the frame. As shown in FIGS. **15** and **16**, the water catches **84***a*, **84***b* are connected by an elongate member **162** that is free to pivot about a point approximately midway between the water catches. A steel cable **92***a* enclosed within a brake line hose connects the right water catch **84***a* to the latch bolt handles **94***b* on the left side of the frame. Similarly, another steel cable **92***b* enclosed within another brake line hose connects the left water catch **84***b* to the latch bolt handles **94***a* on the right side of the frame. The lever arm **98** of the spigot **110** is connected to the latch bolt handles **94***a*, **94***b* on the left and right sides of the frame.

The power plant **10** may include a control system **22** for operating the reciprocating engines **14***a*, **14***b* in alternating (or lead-lag) operation. The water catches **84***a*, **84***b*, spigot lever **98**, and latch bolt handles **94***a*, **94***b* may interconnect to form a mechanical control system for the power plant. For example, in FIG. **15** the right side bucket mounting frame **54***a* is in the bucket fill position, resting on the pair of latch bolts **58***a*. In this operable configuration, the right side bucket mounting frame is latched to the frame **12** such that the right side bucket is positioned under the right side bucket fill port **90***a*. By contrast, the left side bucket mounting frame **54***b* is unlatched from the frame **12** and the left side bucket assembly **64***b* is free to descend with the added weight of water that would be contained in the left side bucket **76***b*. The left side water catch **84***b* is positioned at the top of the ramp **90** near the left side bucket discharge station **68***b*. Accordingly, the left side water catch **84***b* is positioned to harness kinetic and potential energy from the water discharged at the left side bucket discharge station **68***b*. More particularly, the energy transfer may be sufficient to propel the water catch **84***b* down the ramp **90** and to pull the steel cable **92***b* that connects the left side water catch **84***b* to the right side latch bolt handles **94***a*, and by extension the spigot lever **98**, and the left side latch bolt handles **94***b*. Additionally, the energy transfer may be sufficient to simultaneously pivot the right side water catch **84***a* to the top of the ramp **90** near the right side bucket discharge station **68***a*.

By contrast, in FIG. **16** the bucket mounting frame **54***b* on the left side rests on the pair of latch bolts **58***b*. In this operable configuration, the left side bucket mounting frame **54***b* is latched securely to the frame **12** and the left side bucket assembly **64***b* is positioned underneath the left side bucket fill port **90***b*. By contrast, the right side bucket mounting frame **54***a* is unlatched from the frame **12** and the right side bucket assembly **64***a* is free to descend with the added weight of water that would be contained in the right side bucket **76***a*. The right side water catch **84***a* is positioned at the top of the ramp **90** near the right side bucket discharge station **68***a*. Accordingly, the right side water catch **84***a* is positioned to harness kinetic and potential energy from the water discharged at the right side bucket discharge station **68***a*. More particularly, the energy transfer may be sufficient to propel the water catch down the ramp **90** and to pull the steel cable **92***a* that connects the right side water catch **84***a* to the left side latch bolt handles **94***b*, and by extension the spigot lever **98**, and the right side latch bolt handles **94***a*. Additionally, the energy transfer may be sufficient to simultaneously pivot the left side water catch **84***b* to the top of the ramp **90** near the left side bucket discharge station **68***b*.

In use, water is delivered to the equalization tank **102** at the top of the power plant. Referring to FIG. **4**, under gravity flow, water exits the equalization tank **102** through a series of pipes and fittings **164***a*, **164***b* and is delivered to the spigot **110** which is positioned over the right side drop basin **114** or the left side drop basin **116**. Referring to FIG. **15**, the spigot **110** initially may be positioned above the right side drop basin **114** to deliver water to the right side bucket **76***a*, as the left side bucket **76***b*, which has already been filled with water, descends. The right bucket mounting frame **54***a* is seated securely on the right side latch bolts **58***a*. This positions the right side bucket assembly **64***a* under the water discharge port **90***a* at the right side bucket fill station **66***a*. Referring to FIG. **3**, as the left side bucket assembly **64***b* descends from the left side bucket fill station **66***b* to the left side bucket discharge station **68***b*, the left side bucket mounting frame **54***b* pulls the left side drive chain **118***b* over the left side transmission gear **44***b*. The rotation of the left side transmission gear **44***b* rotates the left side ring gear **46***b* and the left side ring gear **46***b* rotates the left side power gear (not shown) that is fixed on the power shaft **16**. Toward the end of the power stroke, the left side bucket assembly **64***b* approaches the left side trip switch activator **72***b*. Referring to FIG. **10**, the trip switch activator **72** lifts the lever arm **144** up to release the strike **132**. As depicted in FIG. **17**, the unlatched bucket **76***a* rotates away from the bucket mounting frame **54***a* and the water inside the bucket is dumped. This produces a weight imbalance between the empty bucket **76***a* and the counterweight **120***a*, which descends pulling the bucket mounting assembly **64***a* upward. As the bucket assembly **64***a* passes by the horizontal brace **74**, the longitudinal member (or bucket kick) **160***a* on the bottom of the bucket **76***a* hits the horizontal brace **74**. The force of this collision pivots the bucket **76***a* into an upright, vertical position and re-latches the bucket to the bucket mounting frame **54***a*. Referring to FIG. **15**, water discharged from the bucket **76***b* falls on the left side water catch **84***b* and pushes it down the ramp **90**. The movement of the left side water catch **84***b* pulls the attached cable **92***b*, which redirects the spigot **98** to the left side water drop basin **116** and retracts the right side latch bolts **58***a* to release the right side bucket mounting frame **54***a* and start the power stroke of the right reciprocal engine **14***a*. By contrast, the left side bucket mounting frame **54***b* moves upward and slides against the angled edges of the latch bolts **58***b*. The angled edges of the latch bolts allow the left side bucket mounting frame **54***b* to push the latch bolts **58***b* into the frame and pass. Once the bucket mounting frame passes the latch bolts **58***b*, the respective latch springs re-extend the latch bolts **58***b*. The bucket mounting frame **54***b* is raised by the counterweight **120***b* until the top of the cross member of the bucket mounting frame **150***b* contacts the left side fill position stop **56***b*. The left side bucket mounting frame **54***b* then seats securely on the latch bolts **58***b*. This positions the left side bucket **76***b* under the water fill port at the left side bucket fill station **66***b* (FIG. **12**). Preferably, the left side bucket **76***b* will fill to near capacity during the time the right side bucket assembly **64***a* descends from the right side fill station **66***a* to the right side discharge station **68***a*. Upon reaching the right side discharge station **68***a*, the right side trip switch activator **72***a* releases the right side locking mechanism. Water in the right side bucket **76***a* is discharged. The right side bucket assembly **64***a* is raised by the counter weight **120***a* and reset to the right side bucket fill station **66***a* in the manner described for the left side reciprocating engine **14***b*. In this manner, lead-lag operation of the reciprocating engines **14***a*, **14***b* of the power plant **10** may be implemented.

FIG. **18** shows a schematic view of a power plant according to the present invention. The power plant **10** may be situated down gradient of a hatchery fish tank **166** and up gradient of a pond **168**. The power plant **10** may be designed for low head and low flow operating conditions. More specifically, the power plant may operate with a water flow of 5 gallons per minute or less and a total head of approximately 5 feet. The power plant, however, may be designed for larger (or smaller) flows. For instance, at larger flow rates the buckets may be greater in size than 5-gallon buckets. Thus, the bucket and bucket assemblies and other components may be sized or optimized based on the flow rate. As shown in FIG. **18**, a fish tank **166** may be supplied water for a single pass flow through by a spring or other water supply having a total dynamic head of approximately 18 feet.

Discharge from the hatchery fish tank may drain to a collection reservoir or equalization tank **102** associated with the low flow power plant. At a discharge flow rate of 5 gallons per minute, the low flow power plant may be operable provided there is sufficient vertical elevation between the collection reservoir and the discharge of the low flow power plant. In the example shown in FIG. **18**, the difference in elevation between the collection reservoir **102** and the discharge of the low flow power plant is approximately 6 feet. The discharge of the low flow power plant may flow under gravity through a conduit or channel **172** to a watercourse or sanitary sewer.

In the example depicted in FIG. **18**, the power plant discharge flows by gravity through a buried pipe **172** to a pond **168** situated at a lower elevation. The low flow power plant depicted in FIG. **18** may accumulate water as a working fluid under low flow conditions and transfer the potential energy of the accumulated water into a continuous rotational movement of a drive shaft. The rotating driveshaft may be coupled to a device and used as a source of mechanical power. For example, the rotating drive shaft may be connected to a pump that may be used to recycle water from the pond **168** to the fish tank **166**. In another example, the drive shaft may be coupled to an aeration system.

Referring to FIG. **19**, the rotating driveshaft **16** may be coupled to a generator **176** which transforms the rotational movement of the driveshaft into electricity. The electricity may be used to power an electrical device **178**, including, without limitation, process controls, a computer, communication devices, a crank radio, a battery charging station, or other electrical or electronic equipment.

Referring to FIG. **20**, the rotating driveshaft **16** may be coupled to a hydraulic pump **182** which may be used to force hydraulic working fluid through a hydraulic circuit. In this manner, hydraulic fluid may be transmitted to a hydraulically driven apparatus **184** (e.g., a hydraulic motor or cylinder) from a reservoir **186**.

Referring to FIG. **21**, the power plant **10** may be connected in series such that the discharge of one unit at a higher elevation is collected and conveyed to another unit situated at a lower elevation. For example, in FIG. **21** four low flow power plants of FIG. **1** **10***a*, **10***b*, **10***c*, **10***d* are combined in series. Multiple unit configurations may be used in buildings or suitable topographic areas to capture energy from captured storm water, discharged grey water or waste water. As described above, the gearing of the reciprocating engines may be adjusted to accommodate differing flow conditions. The power take off **174***a*, **174***b*, **174***c*, **174***d* of the four units depicted in FIG. **12** are each connected to a hydraulic pump **180***a*, **180***b*, **180***c*, **180***d*, which are connected in series to operate a hydraulic device **184**. Other process controls, such as flow rate valves, may be used to regulate operation of the power plant. The power for operating these process controls and equipment may be derived from one or more of the low flow power plants in a multiple unit configuration.

While it has been illustrated and described what at present are considered to be preferred embodiments of the present invention, it will be understood by those skilled in the art that various changes and modifications may be made, and equivalents may be substituted for elements thereof without departing from the true scope of the invention. Additionally, features and/or elements from any embodiment may be used singly or in combination with other embodiments. Therefore, it is intended that this invention not be limited to the particular embodiments disclosed herein, but that the invention include all embodiments falling within the scope and the spirit of the present invention.

What is claimed is:

1. An apparatus for harnessing power from a low flow source of working fluid comprising:

a power shaft which comprises,

a first end,

a second end spaced from the first end, and

a first power gear disposed between the first end and the second end;

a first reciprocating engine situated proximate to the power shaft and connected to the first power gear for delivering a power stroke and which comprises
a first bucket assembly which includes
a first bucket mounting frame,
a first bucket,
a first connecting mechanism that connects the first bucket to the first bucket mounting frame to form a first hinge that pivots about a first pivot axis such that the first bucket creates a turning moment about the first pivot axis, and
a first locking mechanism for selectively locking the first bucket in the first bucket mounting frame;
a first bucket filling station for filling the first bucket with working fluid and which comprises
a first upper stop,
a first lower stop, the first lower stop being selectively moveable between a first deployed position and a first retracted position, and
a first lever for selectively retracting the first lower stop and which is moveable between a first closed position and a first open position such that when the first lever is in the first closed position the first stop is in the first deployed position and when the first lever is in the first open position the first stop is in the first retracted position;
a working fluid distribution system for delivering working fluid to the first reciprocating engine which comprises,
a tank for storing working fluid;
a first fill port in fluid communication with the tank; and
a working fluid discharge system for discharging working fluid from the first reciprocating engine to complete the power stroke, and which comprises a first trip switch activator for releasing the first bucket assembly locking mechanism; and
a control system for resetting the first reciprocating engine following the power stroke.

2. The apparatus of claim **1**, wherein the first reciprocating engine further comprises:
a first counterweight,
a first drive chain which comprises
a first portion being connected to the bucket assembly,
a second portion being connected to the first counterweight, and
a third portion interconnecting the first portion and the second portion, and
a first gear set which comprises a first ring gear in working contact with the first power gear for transmitting rotational motion to the power shaft.

3. The apparatus of claim **2**, wherein the first reciprocating engine further comprises a first positioning gear being disposed between the first gear set and the first counter weight.

4. The apparatus of claim **2**, wherein the first gear set further comprises:
a first transmission gear in working contact with the third portion of the first drive chain, and
a first ratcheting mechanism being disposed between the first ring gear and first the transmission gear such that rotating the first transmission gear drives the first ring gear in the same direction and counter-rotating the first transmission gear does not affect rotation of the first ring gear.

5. The apparatus of claim **4**, further comprising:
a second power gear disposed on the power shaft between the first power gear and the second end; and
a second reciprocating engine proximate to the power shaft and being connected to the second power gear, which comprises,
a second bucket assembly, and
a second gear set which comprises a second ring gear in working contact with the second power gear for transmitting rotational motion to the power shaft.

6. The apparatus of claim **5**, wherein the second reciprocating engine further comprises:
a second counterweight,
a second drive chain which comprises
a fourth portion connected to the second bucket assembly,
a fifth portion connected to the second counterweight, and
a sixth portion interconnecting the fourth portion and the fifth portion.

7. The apparatus of claim **6**, wherein the second reciprocating engine further comprises:
a second transmission gear in working contact with the sixth portion of the second drive chain, and
a second ratcheting mechanism being disposed between the second ring gear and the second transmission gear such that rotating the second transmission gear drives the second ring gear in the same direction and counter-rotating the second transmission gear does not affect rotation of the second ring gear, and
a second positioning gear being disposed between the second gear set and the second counter weight.

8. The apparatus of claim **5**, further comprising a second bucket filling station which comprises
a second upper stop,
a second lower stop, the second lower stop being selectively moveable between a second deployed position and a second retracted position, and
a second lever for selectively retracting the second lower stop which comprises a second closed position and a second open position such that when the second lever is positioned in a second closed position the second stop is in the second deployed position and when the second lever is in the second open position the first stop is in the second retracted position.

9. The apparatus of claim **8**, wherein the water distribution system further comprises:
an inflow structure in fluid communication with the tank for conveying working fluid to the apparatus,
an outflow structure in fluid communication with the tank,
a first drop basin situated hydraulically down gradient of the tank and located below a first target location,
a second drop basin situated hydraulically down gradient of the tank and located below a second target location,
a spigot in fluid communication with the outflow structure and disposed between the tank and the first and second drop basins, such that the spigot is moveable from the first target location to the second target location;
a first fill port in fluid communication with the first drop basin and situated above the first bucket assembly,
a second fill port in fluid communication with the second drop basin and situated above the second bucket assembly.

10. The apparatus of claim **9**, wherein the first locking mechanism comprises
a first strike secured to the first bucket, and
a first catch, which comprises a first lever arm, and which is secured to the first bucket mounting frame, the first catch being movable between

a first closed configuration such that the first strike is interlocked with the first catch to selectively lock the first bucket in the first bucket mounting frame, and

a first open configuration such the first strike is not interlocked with the first catch, and the first catch is biased in the first closed configuration and oscillation of the first lever arm away from the first closed configuration positions the catch in the first open configuration.

11. The apparatus of claim **10**, wherein the first bucket mounting frame includes a plurality of guides to restrain movement of the bucket mounting frame, and the working fluid discharge system further comprises a first pair of kick plates disposed below the first bucket assembly and a second pair of kick plates disposed below the second bucket assembly.

12. The apparatus of claim **11**, wherein the control system further comprises:

a first ramp situated below the first pair of kick plates,

a first water catch disposed on the first ramp, the first water catch being linked to the second lever such that movement of the first water catch down the first ramp causes the second lever to move to the second position, and causes the spigot to move to the first target location.

13. The apparatus of claim **12**, wherein the control system further comprises:

a second ramp situated below the second pair of kick plates,

a second water catch disposed on the second ramp, the second water catch being linked to the first lever,

such that movement of the second water catch down the second ramp causes the first lever to move to the second position, and causes the spigot to move to the second target location.

14. The apparatus of claim **13**, wherein movement of the first water catch down the first ramp causes the second water catch to move up the second ramp, and movement of the second water catch down the second ramp causes the first water catch to move up the first ramp.

15. The apparatus of claim **14**, further comprising a frame for supporting the first reciprocating engine.

16. The apparatus of claim **15**, wherein the first bucket includes a first kick and the frame includes a brace such that upward movement of the first bucket assembly away from the first pair of kick plates causes the brace to strike the first kick, rotating the first bucket into a vertical orientation and setting the first locking mechanism in the first closed configuration.

17. The apparatus of claim **1**, wherein the second end is connected to a mechanical device such that rotation of the second end powers the mechanical device.

18. The apparatus of claim **17**, wherein the mechanical device is selected from the group consisting of a pump or a generator.

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